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Technical and Philosophical Aspects of Ocean Disposal

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ABSTRACT

Seven major technical aspects of ocean disposal are discussed in this report. They include qualitative and quantitative aspects of waste materials, disposal methods, transport of materials through water, effects of wastes, legislation, regulations, critical quantities, disposal sites, alternatives to ocean disposal, and future trends of this disposal method. Twenty-two philosophies relating to ocean disposal are discussed, and relationships between technical aspects and philosophies are shown in figures.

This report aims to serve as a reference for educational, governmental, industrial, and decision-making bodies.

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CHAPTER I

INTRODUCTION

Ocean disposal of wastes is not a new idea, although it is only in recent years that this issue has received considerable attention. Man is concerned about the condition of the ocean because it is a valuable source of many resources. Fishing is often the most publicized use of the sea. The United States catch is approximately three million metric tons (U.S. Department of Commerce, 1974). Marine plants, such as algae and seaweeds, are valuable sources of chemicals and other substances useful to man. Shipping and transportation are other important uses of the ocean. The sea and its coastal areas provide recreation for many people. Nonliving resources of the ocean provide man with useful substances such as minerals, oil and gas. The ocean is also important in that it is critical to maintaining the world's environment and providing the basis for the hydrological system.

The multiple use of the ocean has lead to conflicts. People began voicing their concern over the condition of the oceans, and the result of these outcries was the passage of two laws important in determining the role of ocean disposal: the Federal Water Pollution Control Act Amendments of 1972 and the Marine Protection, Research and Sanctuaries Act of 1972. The provisions of these laws reflected the concern and public awareness that coastal and ocean resources are vital to man.

Controversy has arisen over the issue of ocean disposal of materials because there is the question of whether the materials are considered wastes or potential natural resources. A substance is considered a pollutant if it changes the water quality so that the beneficial uses of the ocean are adversely affected. The National Water Commission defined water pollution (Bascom, 1974):

> Water is polluted if it is not of sufficiently high quality to be suitable for the highest uses users wish to make of it at the present or in the future.

The prevention of marine pollution lies within the realm of man; only he can make the decision to preserve the integrity of the ocean.

Purpose

The purpose of this presentation was to compile a document that examined the technical and philosophical aspects of ocean disposal. People have often formulated opinions about the ocean disposal of waste materials without having all the facts at hand. This presentation was intended to serve as a reference for educational, governmental, industrial or other relevant entities and their personnel who have need of this information.

Chapter I includes a section on oceanography and its major geological, physical, chemical and biological parameters. The purpose of this discussion is to familiarize the reader with some of the important terms of oceanography that will be relevant in later chapters. Chapter II covers the principal technical aspects of ocean disposal, and it includes discussion of the qualities and quantities of waste materials, disposal methods, transport of the materials, relevant legislation, disposal sites, effects of the wastes, alternatives, and future trends. This chapter focuses mainly on disposal practices off the coasts of the United States. Chapter III presents some of the more well-known philosophies of ocean disposal. Both sides of each philosophical issue are presented whenever possible so that the reader may recognize the truths and fallacies of these issues if they are known. Chapter IV summarizes the text and shows the interrelationships between the technical and philosophical issues.

Procedure

Information for this presentation was collected from all known sources and carefully examined to determine its relevancy. All available literature pertinent to this subject was thoroughly examined. Federal agencies were contacted and information was received in the form of documents, permits and personal correspondence. These materials were then assembled as a report to be used in the future as a guideline.

Oceanography As It Relates to Ocean Disposal

Oceanography is the realm of science that deals with the ocean in all its aspects. The field can be subdivided into four main areas: geological, which is concerned with the structure of the ocean bottom; physical, which deals with the properties of ocean water in motion; chemical, which is concerned with the chemical reactions occurring in the oceans; and biological, which includes the study of life in the oceans (Turekian, 1968). This section is a brief summary of the major principles and processes and merely serves as an introduction to the marine environment.

Geological aspects. Included are the study of coasts and shorelines; the continental shelf; the continental slope leading down to the deep ocean; and the deep ocean floor with its occasional basins and trenches (Smith and Brown, 1971). The bottom relief, and rock and sediment types are of importance in determining the fate of waste materials.

The most productive regions of the ocean are in the coastal areas above the continental shelf. Regions beyond these productive areas begin to have bottoms with varied formations. The continental shelf is a platform surrounding the continents and it slopes seaward at a ratio of 1:1000. The shelf break marks the seaward extent of the shelf and occurs at depths between 10 and 500 meters with an average of 200 meters. The width of the continental shelves varies widely. For example, the shelf off the east coast of the United States ranges in width from a mile or two at Miami to over 200 miles off Newfoundland (Smith and Brown, 1971). The continental slope, the next zone, is separated from the landward side by the shelf break, here, the gradient becomes steeper than 1:40 (Turekian, 1968). The lower limit is where the slope grades into the surface of the deep ocean floor and this is termed the continental rise. Slopes can have such features as hills and basins, plateaus and terraces. Canyons are features of the slope and shelf, and they act as channels for the seaward transport of sediment. The deep ocean is characterized by such features as abyssal hills and plains. The hills stick up through layers of sediment of varying thickness, and the plains are very smooth with gradients between 1:1000 and 1:10,000 (Turekian, 1968).

Sediments on the ocean bottom are highly varied, and these are significant to forms of benthic marine life. Sediments of the bottom are governed by sea floor erosion, transportation and deposition. These forces may also determine the fate of waste materials on the bottom. Waste materials may become harmful to benthic habitats if they build up in significant quantities.

Physical aspects. The physical factors which affect the behavior of wastes in the ocean are temperature, salinity, density, illumination, currents and waves. Certain parameters affect marine life and changes in these parameters can be detrimental to organisms.

The temperature of the oceans varies greatly with the latitude, season of the year, solar radiation, and depth. The sea temperature decreases vertically from the surface to the great depths. The ocean can be divided into several layers according to the vertical variation in temperature. The shallow surface layer generally maintains a high close-to-surface temperature and this layer is followed by the thermocline layer which is characterized by temperature rapidly decreasing with depth. The next stratum is the deepwater layer in which the temperature decreases gradually with depth and at its lower end the temperature scale becomes asymptotic to the low temperature of the bottom-water layer (Chow, 1964). Higher temperatures affect organisms by reducing the concentration of dissolved gases in the water, inactivating enzymes, causing increased permeability of cell membranes, and increasing the rate of evaporation (Zottoli, 1973). Low temperatures adversely affect organisms by causing insufficient integration between nervous coordination and body metabolism.

A solution of metallic salts, organic materials, and atmospheric gases formulates the composition of seawater. Since the major cations that form salts are in relative proportions, the salt content (salinity) can be determined by measuring the amount of chloride in a given water sample. Salinity may be defined as the total amount of solid material in grams contained in one kilogram of seawater, when all the carbonate has been converted to oxide, the bromine and iodine replaced by chlorine, and all the organic material completely oxidized (Zottoli, 1973). Salinity, expressed in parts per thousand, is calculated by the following formula (Turekian, 1968):

salinity = 0.03 +1.805 x chlorinity

The average salinity of ocean water is 35 parts per thousand, and it varies according to temperature, the degree of evaporation, and the amount of freshwater present.

Density is the mass per unit volume expressed in grams per cubic centimeter. It is a function of temperature and salinity. The density of seawater increases with decreasing temperature and with increasing salinity, such as evaporation. Specific gravity, which is the measure of density of a solution relative to that of distilled water at 4°C (Coker, 1962), is of direct and indirect importance in biological processes. Differences in specific gravity between neighboring water masses with unstable stratification result in currents which cause transport and exchange of materials in the ocean (Friedrich, 1969). Thermal and haline discontinuity layers form density discontinuity layers which serve as barriers to the vertical exchange of water, thereby preventing the entry of heat and also the transport of nutrients and gases. Sinking bodies and substances with a specific gravity less than that of water in a discontinuity layer may collect in that layer.

Illumination provides energy that is used by plants during photosynthesis for the formation of organic carbon. Photosynthesis adds large amounts of oxygen to the upper layer of the ocean where it is available for respiration and oxidation. Turbidity, the measure of the extent of light attentuation caused by suspended and colloidal materials in water, can reduce the passage of light through the water column and cause damaging effects to the marine ecosystem.

Each of five major oceans has pronounced gyral, or circular current motion (Figure 1.1). The North Atlantic current system comprises the Gulf Stream, North Atlantic Current, Canary Current North Equatorial Current, and Florida Current, and all these form a gigantic clockwise gyral. The South Atlantic current system, which forms a counterclockwise gyral, is made up of the Benguela Current, South Equatorial Current, Brazil Current, and West Wind Current (Williams, 1962). Regions of the west coast of the United States are affected by North and South Pacific Current Systems.

Circulation of ocean water depends mainly on wind stress and temperature-salinity density factors (Zottoli, 1973). Surface waters are circulated primarily by wind stress, friction of the wind against the sea surface. Temperature-salinity density factors cause water to move from areas of low salinity and thus low density to areas of high salinity and density; these are principally responsible for deepwater circulation. The function of oceanic circulation is to help distribute heat from low to high latitudes and serve as a vehicle for transporting food and oxygen to marine organisms. Currents also distribute permanent and temporary members of the plankton group.

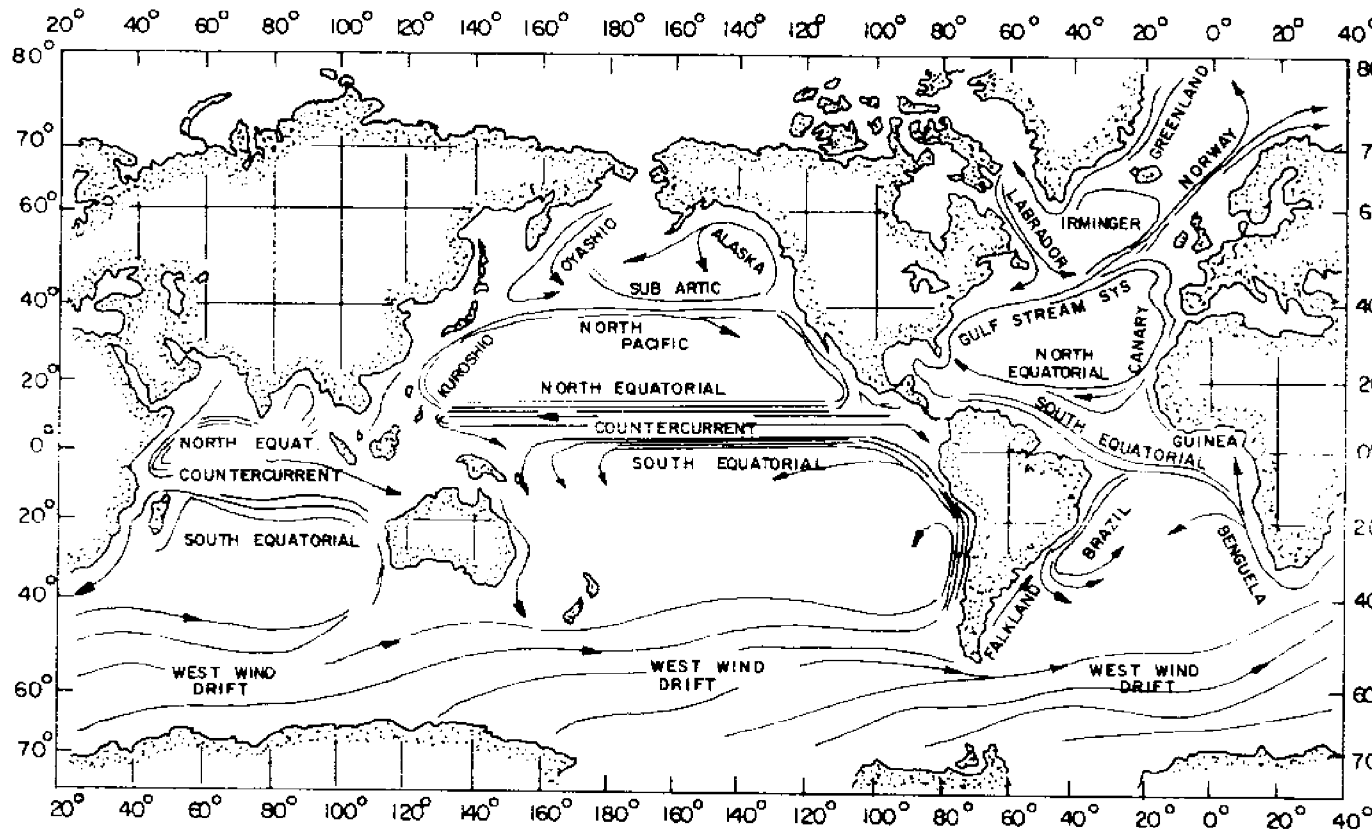

FIGURE I.I. AVERAGE SURFACE CURRENTS OF THE WORLD'S OCEANS.
(WILLIAMS , 1962)

The most common waves in the ocean are generated by winds. When a wind blows over the surface of the ocean, it piles up the water in ridges whose height and periodicity reflect the intensity of the wind (Turekian, 1968). As the waves move away from the source, the smaller waves are eliminated in favor of the longer-period wave, resulting in a pronounced swell. Movement of the surface increases the uptake of oxygen by the water and it alters the reflection of incident light (Friedrich, 1969). Waves are associated with turbulence which may move pelagic organisms into deeper water.

Chemical aspects. Chemical parameters are important because of their impact on biological processes. This discussion will include the composition of seawater and its dissolved gases and nutrients.

Seawater is made up of both major and minor constituents. Table 1.1 lists the major components and their concentrations. The principal dissolved salts account for over 99 percent of the ocean's salinity Seawater has a weak alkaline reaction due to the percentage of anions and cations in the salts of the water. Trace elements present in seawater account for only about 0.02 to 0.03 percent of the salinity (Friedrich, 1969). These elements, although in small amounts, are indispensable for biochemical processes. Marine organisms are able to selectively accumulate trace substances.

The chief gases dissolved in the ocean are oxygen and carbon dioxide. In addition to these, nitrogen and rare gases such as helium and neon are also absorbed by seawater. The effect of these gases is still unknown; although nitrogen may chemically be involved due to

TABLE 1.1 Concentration of the Major Components of Seawater* (Turekian, 1968)

Component	Grams per Kilogram of Water
Chloride	19.353
Sodium	10.76
Sulfate	2.712
Magnesium	1.294
Calcium	0.413
Potassium	0.387
Bicarbonate	0.142
Bromide	0.067
Strontium	0.008
Boron	0.004
Fluoride	0.001

*For a salinity of 35 parts per thousand.

the presence of nitrogen-fixing and nitrogen-producing bacteria (Friedrich, 1969).

The oxygen content of seawater varies between zero and 8.5 milliliters per liter, mainly within the range 1 to 6 (Tait, 1968). High oxygen values occur at the surface, where dissolved oxygen tends to equilibrate with atmospheric oxygen dependent upon temperature and salinity. An increase in temperature and/or salinity causes a decrease in the saturation value for oxygen. In deeper zones inhabited by plants, they may consume as much oxygen as they produce, so that the net contribution is zero. Living processes require energy and for these oxygen processes are necessary. Inadequate oxygen causes an unsuitable environment for marine life and leads to anaerobic conditions.

Carbon dioxide is derived from the carbonate system in the form of bicarbonates of sodium, potassium, and calcium. The form carbon dioxide assumes in water is a function of salinity, temperature, and pressure. The pH (acidity) of seawater is closely tied to the carbon dioxide equilibrium system. Carbon dioxide is relatively soluble in seawater and this is important, because the synthesis involving the union of carbon dioxide and water in sunlight is the basis of all life.

Plant matter depends on a supply of the so-called nutrient salts, especially phosphates and nitrates. The absence of these compounds, which are usually present in low concentration, is enough to stop plant production. The replenishment cycle of these nutrients includes a net downward motion of particulate matter that is essentially balanced by a net upward flow of these constituents in solution as a result of water circulation (Smith and Brown, 1971). Excessive amounts of nitrates and phosphates may cause biostimulation, the accelerated fertilization of plants, which is detrimental to aquatic life.

Biological aspects. This branch of oceanography deals with life in the marine environment. Marine life depends on the geological, physical and chemical properties and their interactions with others. Living space in the ocean extends from the intertidal zone along the shore to the bottom of the deepest trenches and consists of the sea surface, water of the ocean, and sea floor (Weyl, 1970). Diverse environments are classified by depth and habitat (Figure 1.2). The organisms according to habitat are divided into two major groups: benthic and pelagic, which includes plankton and nekton or all life in the open water.

Plankton are organisms that drift with the currents. Horizontal water movements control the position of plankton, which play a key role in the ocean ecosystem. Plankton are further subdivided into phytoplankton and zooplankton. Phytoplankton consist of drifting plant matter such as diatoms and dinoflagellates. Zooplankton are slightly mobile animals such as small crustaceans, swimming molluscs, coelenterates, and free-swimming larvae of benthic organisms.

Nekton are animals capable of actively swimming at speeds which enable them to outstrip ocean currents and tidal streams, and even to undertake substantial migration. This category includes adult fish, squids and cuttlefish, marine mammals, and a few reptiles.

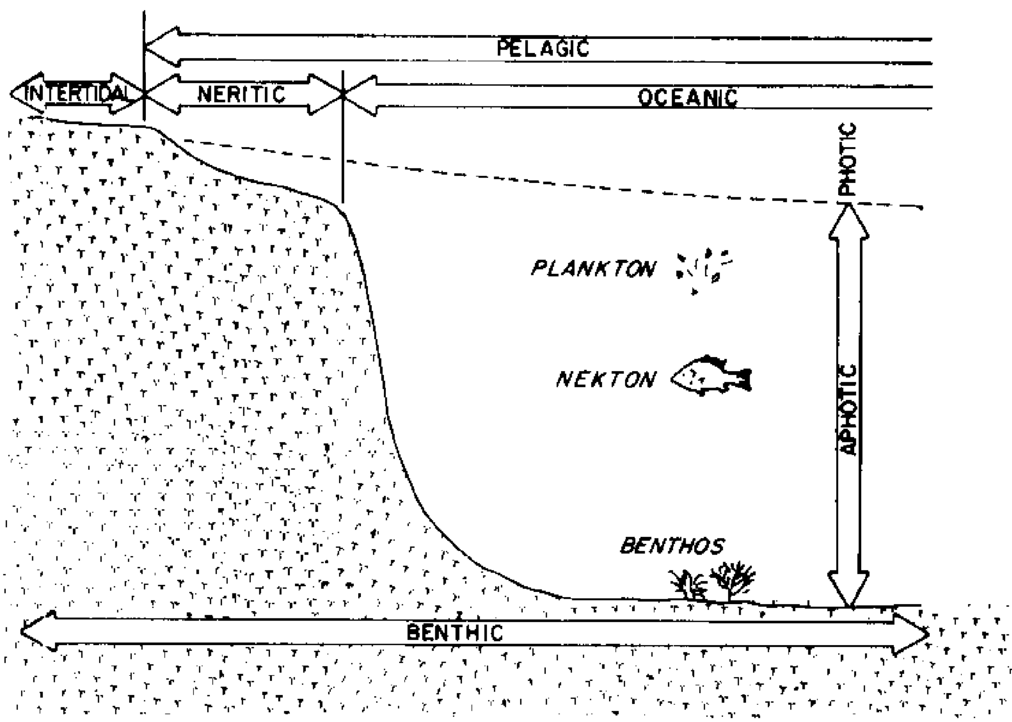

FIGURE 1.2 CLASSIFICATION OF MARINE ENVIRONMENTS
(WEYL , 1970)

Benthos are organisms that live in or on the sea bottom. Infauna live buried or partly buried in sand, mud, or silt, while epifauna live on submerged or tidal rocks or on the seabed surface. Nektobenthos live at the bottom but can move quickly on the seabed. Crabs and prawns are of this organism group. Some organisms spend one stage of life as benthos and another stage as plankton or nekton (Thorson, 1971).

The intertidal zone is the shallowest region and ranges between the high- and low-water lines. The shallow ocean over the continental shelves to a depth of approximately 200 meters is the neritic zone, while the oceanic region extends from the edge of the continental shelf to the deep trenches. The ocean is also zoned vertically according to light penetration. The photic zone is illuminated by sunlight and its depth, which depends on the clarity of the water, can range from over 100 meters to only a few meters in some coastal areas. The aphotic zone is a region of total darkness (Weyl, 1970).

The food chain is a vital aspect of the marine environment. It begins with solar radiation penetrating the photic zone where the sunlight is absorbed by the water and plants. Plants use sunshine along with nutrients and carbon dioxide in their growth and reproduction processes known as photosynthesis. Oxygen is produced as the result of this reaction. These plants known as phytoplankton are eaten by zooplankton which in turn are devoured by larger animals. Organisms not eaten either die and decay to replenish the nutrient supply or become food for scavengers. The cycle begins anew when plants utilize the nutrients supplied by decaying organisms and the carbon dioxide expellec by animals in respiration. Figure 1.3 illustrates that plants and animals essentially work together. Plants put the oxygen into the water which the animals use, and they take the carbon dioxide produced by animals in exchange. What one produces the other needs. When one link in the food chain is broken, the entire marine ecosystem and even man suffers (Williams, 1962).

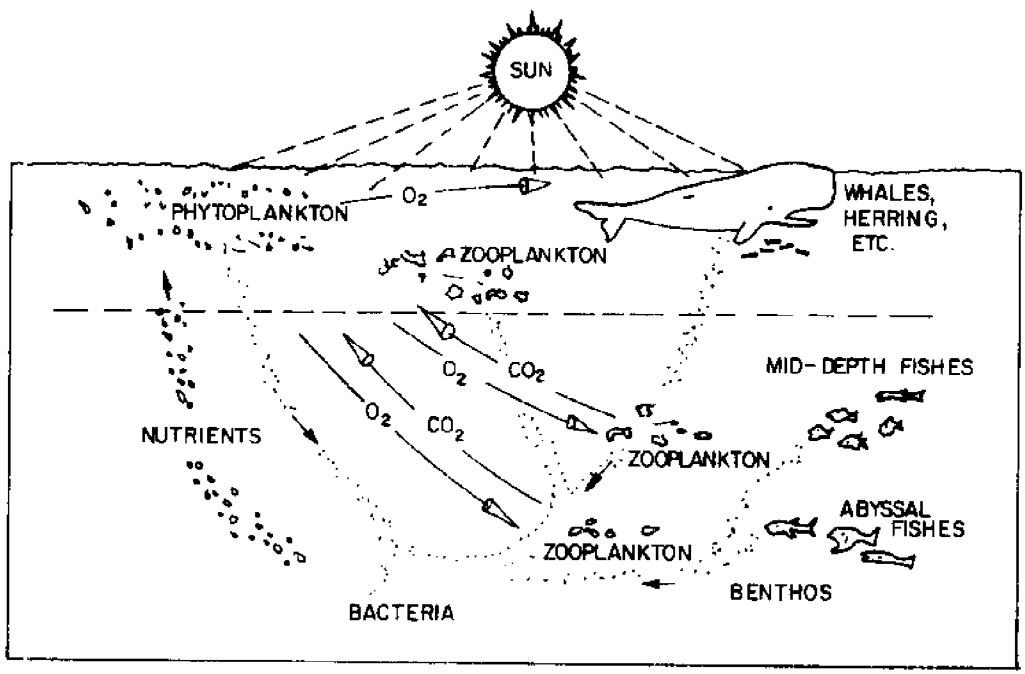

FIGURE 1.3. A SCHEMATIC REPRESENTATION OF SOME MARINE FOOD CHAINS

(WILLIAMS , 1962)

CHAPTER II

TECHNICAL ASPECTS OF OCEAN DISPOSAL

The technical phases involved in the ocean disposal of waste materials are very numerous and detailed in description. This chapter only covers the major technicalities in summary form.

Types of Waste Materials

Materials disposed of in the ocean are divided into seven major categories: dredged material, industrial wastes, domestic sewage wastes, refuse, radioactive wastes, construction and demolition debris, and military wastes. Most of the wastes being ocean disposed of at the present fall within the first three groups.

Dredged materials. The largest percentage of waste disposed of in the ocean is in the form of dredged material. As defined in the Marine Protection, Research and Sanctuaries Act of 1972 (92nd Congress of the United States, 1972b), "dredged material" means "any material excavated or dredged from the navigable waters of the United States." Dredging operations are usually performed in estuaries where the adjacent watershed and its drainage system provide the major source of sediment; however, other deposited sediments may be the result of littoral drift, incoming tides, estuary banks, mud flats, and man-made waste discharges (Clark, et al., 1971).

These sediments consist mainly of sand, silt, and clay, and they range in size from a fraction of a micron to a few centimeters. These sediments may also contain variable amounts of organic and inorganic solids. The U. S. Army Corps of Engineers estimated that approximately one-third of the dredged material is polluted (Council on Environmental Quality, 1970). Contamination results from the deposition of pollutants from industrial, municipal, agricultural, and other sources on the bottom of waterways. Besides particulate and sorbed organic matter, pollutants include heavy metals in particulate, adsorbed, and chelated forms and solids such as rock, wood, metal, glass, and other debris (National Academy of Sciences, 1975).

The majority of the dredging is done directly by the Corps of Engineers, while the rest is done by private contractors under the specifications of Corps permits. Most of the dredging operations are conducted with hydraulic pipeline dredges and clam-shell dredges (U.S. Department of Commerce, 1974). The dredged materials are usually disposed of in coastal waters of less than 100 feet deep, generally not more than a few miles from the dredging site (Dallaire, 1971)

Industrial wastes. The composition of industrial wastes is as varied as the processes which produce them. The manufacturing and processing operations include petroleum refining, steel and paper production, pigment processing, chemical manufacturing, oil-drilling processes, metal processes, and many others. The following discussion just briefly describes some of the industrial wastes that are disposed of in the ocean (Smith and Brown, 1971).

Refinery wastes evolve from the chemical refining processes used to extract products from crude oil. These wastes consist of spent caustic solutions, sulfuric acid sludges, dilute water solutions, spent catalysts, petrochemical wastes, and cleaning wastes. These wastes can contain pollutants such as cyanides, sulfur compounds, heavy metals mercaptides, hydrocarbons and many other compounds.

Spent sulfuric acid wastes are typically seven percent free acid and up to 30 percent ferrous sulfate. This waste is produced in steel mills by pickling operations. An acid-iron waste results from the titanium pigment industry. In the process, iron is digested with sulfate and inert solids.

Pulp and paper mill operations produce various wastes: sulfate cooking solution, "black liquor," and organic constituents of wood. Wastes from chemical manufacturing and laboratories are usually toxic and very complex in composition and behavior. Waste chemicals include chlorinated hydrocarbons, mercuric and arsenical compounds, alkalies, anilines, organic acids, cyanides and other toxic chemicals.

Oil wastes are derived from a variety of industrial processes. Oil drilling wastes are mainly drilling muds containing oil, barite and diatomaceous clays. Waste oils are the residues of tanker operations and operations on land such as service stations and tank cars.

Domestic sewage wastes. Sewage wastes from municipalities are disposed of in the ocean in various states. Wastewater enters into the sea through outfalls as raw, primary, or secondary effluents. Treatment of the wastewaters varies at different locations. Sewage sludge which is dumped mainly from vessels is either a raw primary sludge or a digested sludge.

The composition and concentration of sewage vary with the hour of the day, the day of the week, and the month of the year. Table 2.1 shows the typical composition of domestic sewage. Most of the effluent discharged to the ocean has undergone primary or secondary treatment. Primary effluents result when the wastewater has gone through physical treatment processes such as screening, mixing, and sedimentation. Biological unit processes reduce the organic content of domestic wastewater through bacterial control. Various biological processes include activated sludge, trickling filters and aerated lagoons.

Sludge differs from wastewater in that it has a higher solids content. A primary sludge generally has a solids content of two to three percent with 70 to 80 percent volatile matter of the solids; whereas a well-digested sludge contains about five percent solids which can be increased to 10 percent upon dewatering with 40 to 50 percent volatile matter of the total solids (Clark, et al., 1971). Sludge contains an average of 23 percent oxidizable carbon in soluble and particulate form (National Academy of Sciences, 1975). The dissolved fractions consist mainly of acids and sugars; the particulate organics

TABLE 2.1. Typical Composition of Domestic Sewage (All values except settleable solids are expressed in mg/liter) (Metcalf and Eddy, 1972)

Constituent	Concentration		
	Strong	Medium	Weak
Solids, total	1,200	700	350
Dissolved, total	850	500	250
Fixed	525	300	145
Volatile	325	200	105
Suspended, total	350	200	100
Fixed	75	50	30
Volatile	275	150	70
Settleable solids	20	10	5
Biochemical oxygen demand, 5-day, 20°C (BOD_5-20°)	300	200	100
Total organic carbon (TOC)	300	200	100
Chemical oxygen demand (COD)	1,000	500	250
Nitrogen, (total as N)	85	40	20
Organic	35	15	8
Free ammonia	50	25	12
Nitrites	0	0	0
Nitrates	0	0	0
Phosphorus (total as P)	20	10	6
Organic	5	3	2
Inorganic	15	7	4
Chlorides*	100	50	30
Alkalinity (as $CaCO_3$)*	200	100	50
Grease	150	100	50

*Values should be increased by amount in carriage water.

contain proteins, carbohydrates, fats, esters, and unidentified organics. Table 2.2 illustrates the typical composition of raw and digested sludge as shown in Metcalf and Eddy (1972).

Two major fractions make up the physical composition of sewage sludge solids (U.S. Department of Commerce, 1975). The first group, composed of heavier solids, sinks to the bottom in the vicinity of the disposal site. The second fraction consists of dissolved and suspended solids in the water column, and floatables. The composition and water circulation affect how long the solids remain in the water column.

Solid wastes. Only an insignificant level of marine disposal of refuse and garbage occurs in the United States. These wastes are derived mainly from canneries and from commercial and naval vessels primarily on the Pacific coast. Solid wastes consist of paper products, food wastes, metals, glass, garden wastes, rock, plastics, rubber, textiles, wood and other similar wastes (Council on Environmental Quality, 1970). Many of these are floatable and relatively biodegradable. Solid wastes contain a low percentage of pollutants such as nutrients, oxygen-demanding materials and heavy metals.

Radioactive wastes. These wastes are produced by the nuclear energy industry and are classified as to their activity. High-activity wastes emit hundreds of curies per gallon, while low-activity wastes emit microcuries per gallon (Smith and Brown, 1971). The low-

TABLE 2.2. Typical Chemical Composition of Raw and Digested Sludge (Metcalf and Eddy, 1972)

Item	Raw Primary Sludge		Digested Sludge	
	Range	Typical	Range	Typical
Total dry solids (TS), %	2.0-7.0	4.0	6.0-12.0	10.0
Volatile solids (% of TS)	60-80	65	30-60	40.0
Grease and fats (ether soluble, % of TS)	6.0-30.0	...	5.0-20.0	
Protein (% of TS)	20-30	25	15-20	18
Nitrogen (N, % of TS)	1.5-4.0	2.5	1.6-6.0	3.0
Phosphorus (P_2O_5, % of TS)	0.8-2.8	1.6	1.5-4.0	2.5
Potash (K_2O, % of TS)	0-1.0	0.4	0.0-3.0	1.0
Cellulose (% of TS)	8.0-15.0	10.0	8.0-15.0	10.0
Iron (not as sulfide)	2.0-4.0	2.5	3.0-8.0	4.0
Silica (SiO_2, % of TS)	15.0-20.0	...	10.0-20.0	
pH	5.0-8.0	6.0	6.5-7.5	7.0
Alkalinity (mg/liter as $CaCO_3$)	500-1,500	600	2,500-3,500	3,000
Organic acids (mg/liter as HAc)	200-2,000	500	100-600	200
Thermal content (Btu/lb)	6,800-10,000	7,600*	2,700-6,800	4,000†

*Based on 65 percent volatile matter.
†Based on 40 percent volatile matter.

activity, liquid wastes consist mostly of decontaminated process and cooling waters from reactors, fuel processing, and other operations; whereas, the high-activity, liquid wastes result from the reprocessing of reactor fuel elements (Council on Environmental Quality, 1970). Solid wastes include contaminated laboratory or process equipment, clothing and other items utilized by nuclear plant operations, medical facilities, and research and development activities. The radioactive wastes disposed of in the ocean are usually in concrete-filled drums or containers. Since 1962, no significant levels of these wastes from United States' sources have been disposed of in the ocean (Council on Environmental Quality, 1970).

Construction and demolition debris. These waste materials, which are usually inert, consist of earth and rock from cellar excavations and broken concrete, rubble, and nonfloatable debris from building demolition and highway construction work (Interstate Electronics Corporation, 1973). Presently New York City is the only entity carrying out this type of marine disposal. The type and quantity of materials vary according to the city's construction activity.

Military wastes. This category of waste material includes unserviceable or obsolete shells, mines, solid rocket fuels, and chemical warfare agents (Council on Environmental Quality, 1970). Prior to 1964, the primary waste was from barges and ships. Since then 19 stripped-down World War II Liberty ships were loaded with munitions and scuttled in water depths greater than 4,000 feet (U. S. Department of Commerce, 1974). In the last six operations the weapons were to detonate, but one ship failed to do so and is still located on the continental shelf near Alaska (Council on Environmental Quality, 1970). As of 1970, all ocean disposal of military munition wastes has ceased.

Quantities of Waste Materials

The amounts of wastes vary according to the location and the types of operations producing the wastes. Table 2.3 shows the quantities of wastes disposed of in the ocean according to the geographic location and type of material, exclusive of ocean discharges through outfalls and dredged materials, for the years 1968, 1973 and 1974. Ocean disposal of solid wastes has been reduced to almost total non-existence, while disposal of military and radioactive wastes has been totally phased out. The Atlantic Coast is still responsible for the disposal of the largest quantities of industrial, sewage, and construction wastes from vessels. Figure 2.1 graphically illustrates the amounts of waste materials exclusive of outfall discharges, for the year 1974. As shown on the figure, only two areas are disposing of wastes in sizable amounts other than dredged materials.

Dredged material. This waste accounted for 118 million tons or over 90 percent of the total tonnage (excluding pipe discharges) disposed of in the ocean in 1974 (U. S. Department of Commerce, 1975). Table 2.4 shows the volume of dredged material dumped during 1973-1974. The total volume for 1974 was more than twice the material deposited in the ocean in 1973. The largest increase occurred in the Lower Mississippi Valley Division, while the remaining divisions showed only slight variations in total volumes. Additional dredging

TABLE 2.3. Vessel Discharge Ocean Disposal: Types and Amounts, 1968, 1973, 1974
(National Academy of Sciences, 1976)

WASTE TYPE	ATLANTIC 1968	ATLANTIC 1973	ATLANTIC 1974	GULF 1968	GULF 1973	GULF 1974	PACIFIC 1968	PACIFIC 1973	PACIFIC 1974	TOTAL 1968	TOTAL 1973	TOTAL 1974
Industrial Waste	3,013,200	3,997,100	4,767,000	696,000	1,408,000	950,000	981,300	0	0	4,690,500	5,405,000	5,717,000
Sewage Sludge	4,477,000	5,429,400	5,676,000	0	0	0	0	0	0	4,477,000	5,429,400	5,676,000
Construction & Demolition Debris	574,000	1,161,000	2,242,000	0	0	0	0	0	0	574,000	1,161,000	2,242,000
Solid Waste	0	0	0	0	0	0	26,000	240	200	26,000	240	200
Explosives	15,200	0	0	0	0	0	0	0	0	15,200	0	0
TOTAL	8,079,400	10,587,500	12,685,000	696,000	1,408,000	950,000	1,007,300	240	200	9,782,700	11,995,740	13,635,200

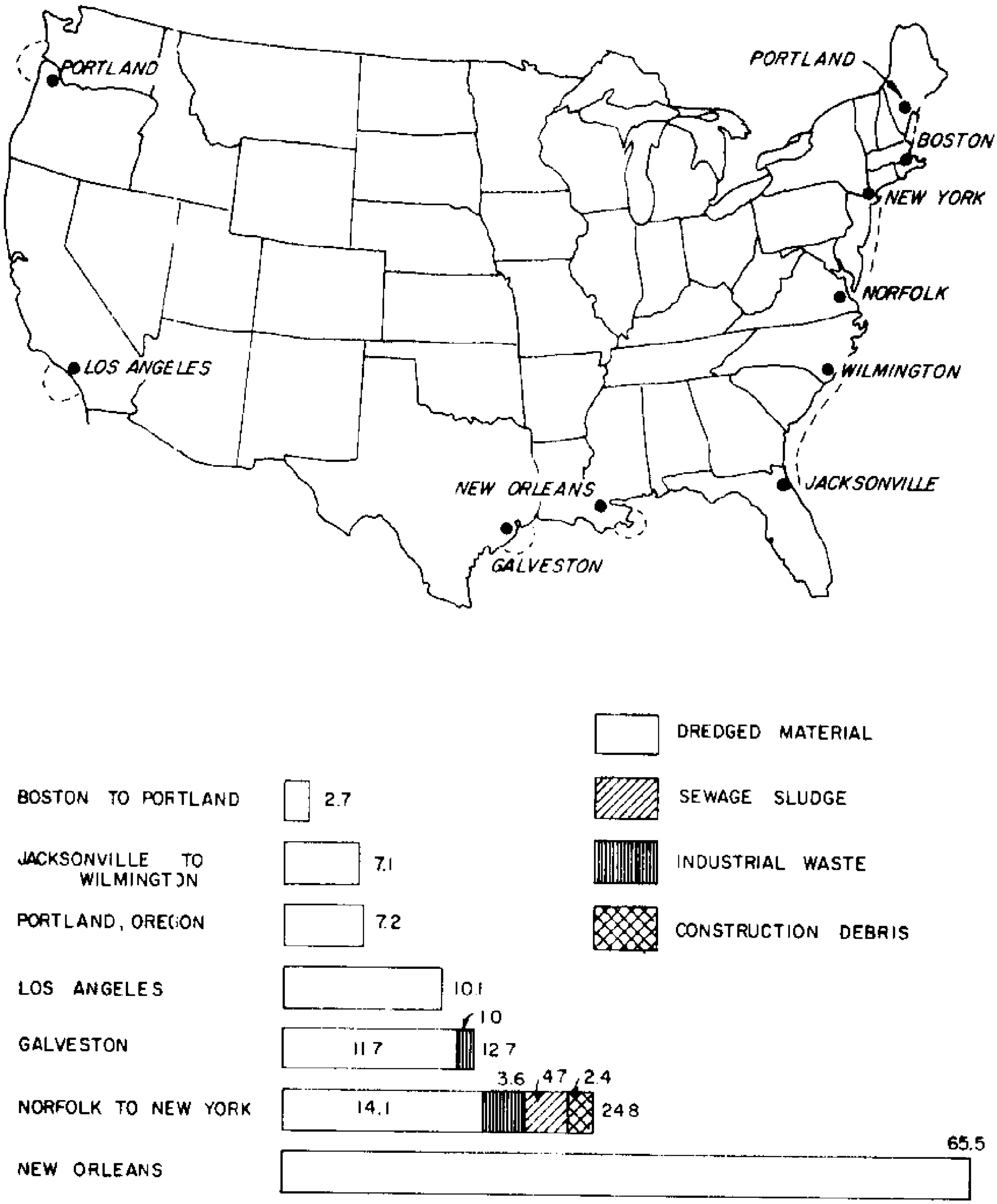

FIGURE 2.1. OCEAN WASTE DISPOSAL BY CATEGORY, 1974 EXCLUSIVE OF OUTFALLS (millions of short tons)

(U.S. DEPARTMENT OF COMMERCE, 1975)

TABLE 2.4. Dredged Material Dumped in Ocean - 1974 and 1973
(Environmental Protection Agency, 1975; Cox, 1975)

	1974			1973		
	Corps of Engineers (cu. yds.)	Permits (cu. yds.)	Total (cu. yds.)	Corps of Engineers (cu. yds.)	Permits (cu. yds.)	Total (cu. yds.)
New England Division	1,340,400	921,800	2,262,200	1,611,000	453,000	2,064,000
North Atlantic Division	8,234,543	3,475,849	11,710,392	10,215,000	2,054,000	12,269,000
South Atlantic Division	2,931,748	2,979,500	5,911,248	7,765,000	---	7,765,000
Lower Mississippi Valley Division	54,600,000	---	54,600,000	---	---	---
Southwestern Division	9,743,982	---	9,743,982	10,781,000	---	10,781,000
South Pacific Division	7,162,918	1,292,500	8,455,418	3,500,000	226,000	3,726,000
North Pacific Division	5,982,280	---	5,982,280	7,586,000	---	7,586,000
Pacific Ocean Division	---	---	---	---	17,000	17,000
Totals	89,995,871	8,669,649	98,665,520	41,458,000	2,750,000	44,208,000

was required due to extensive flooding and silting in the Mississippi River basin over the past few years. Additional increases are predicted during the next few years to several years because of dredging required to deepen channels to the home bases for the Navy's new submarines (U.S. Environmental Protection Agency, 1975).

Industrial wastes. The quantity of these materials discharged to the ocean is increasing. This rise is due to the additional disposal by industries off the East Coast. Companies off the Gulf Coast have diminished their ocean waste disposal to the extent that only one company is presently allowed to practice this method. No one off the West Coast utilizes this method of disposal. The industries on the Gulf Coast have turned to alternate disposal methods. The number of Atlantic disposers is decreasing, but the waste quantities are increasing due to industrial growth while industries are seeking viable alternatives as specified by the Environmental Protection Agency's permit program.

Domestic sewage wastes. Municipal wastes are discharged through outfalls off the coast of the United States, mainly California. Quantities of these wastes discharged from the outfalls vary from one area to another. These quantities are expressed as daily volumes as shown by Berg (1975). For example, the Southern California Bight receives 4.2×10^6 cubic meters of sewage daily from its outfalls. Of this daily total, 3.29×10^6 cubic meters are primary effluent and 0.48×10^6 cubic meters are secondary effluent. Municipal waste treatment outflows discharge approximately 5.2 x 10^{11} kilograms (1.1 x 10^{12} pounds) of solid materials per year into the California Bight (National Academy of Sciences, 1975).

Areas open to the sea with a high density of population such as New York and Philadelphia have turned to ocean disposal of municipal sludges. Ocean disposal of sludge is predominantly off the East Coast. In 1968 about 4.0 million tons of sewage sludge were dumped in the New York Bight, while another 0.5 million tons were disposed of by Philadelphia at a site off Cape May, New Jersey (U.S. Department of Commerce, 1974). This tonnage increased up to approximately 5.7 million tons in the Atlantic area (U.S. Environmental Protection Agency, 1975). The increase in the amount of sewage sludge disposed off the Atlantic Coast is credited to increased plant capacity and additional levels of municipal waste treatment. The problem of sludge disposal will intensify in the future as population and industrialization expand and as present treatment facilities are upgraded to secondary levels, plus treatment of present raw sewage discharges. Sludge will continue to be disposed of in the ocean until suitable disposal alternatives are found.

Construction and demolition debris. Ocean disposal of these wastes is only conducted by New York City due to its lack of onshore disposal area. In 1968, 574,000 tons were disposed of in the New York Bight (U.S. Department of Commerce, 1974). The 1973 total of 1.2 million tons increased to 2.2 million tons in 1974 (U.S. Environmental Protection Agency, 1975). The yearly quantities vary considerably according to the construction activity in New York.

Solid wastes. The ocean disposal of solid wastes at the present time is fairly insignificant, although the solid wastes of this society are estimated to be eight pounds per capita per day in the year 2000 (Council on Environmental Quality, 1970). One of the last disposal operations was off the California Coast in the Long Beach-San Pedro area, but it was suspended. The disposal of cannery wastes in the San Francisco area also was terminated (U.S. Department of Commerce, 1974). The solid waste quantity decreased from 26,000 tons to 200 tons disposed off the Pacific Coast (National Academy of Sciences, 1976).

Military wastes. Since 1970 all ocean disposal of unserviceable munitions has ceased (U.S. Department of Commerce, 1974). Table 2.5 illustrates the total tonnage of ammunition and explosives disposed of in the ocean by scuttling Liberty ships loaded with these wastes.

Radioactive wastes. The amount of radioactive wastes is expected to continue to rise due to the increase in the generation of nuclear power. The quantity of high-level liquid wastes was predicted to increase from 100,000 gallons in 1970 to 6,000,000 gallons by the year 2000 and solid wastes to increase from one million cubic feet in 1970 to three million cubic feet by 1980 (Council on Environmental Quality, 1970). This prediction of increased radioactive wastes should not affect future ocean disposal because sea disposal has been almost nonexistent since the early 1960's due to the Atomic Energy Commission's moratorium on licenses. This reduction was also caused

TABLE 2.5. Explosives and Chemical Munitions, 1964-1970 (Council on Environmental Quality, 1970)

Year	Name	Total Cargo (tons)	Nature of Cargo	Net Explosives (tons)	Disposition
1964	S.S. John F. Shafroth	9,799	A&E	Unknown	SDW
	S.S. Village	7,535	A&E	Unknown	SDW
1965	M.V. Coastal Mariner	4,040	A&E	512	D @ 1,000'
	S.S. Santiago Iglesia	8,715	A&E	408	D @ 1,000'
1966	S.S. Issac Van Zandt	7,500	A&E	1,625	D @ 4,000'
	S.S. Horace Greely	6,033	A&E	442	D @ 4,000'
1967	S.S. Robt. L. Stevenson	6,600	A&E	2,327	S
	S.S. Corporal Eric G. Gibson	9,005	Chem.	None	SDW
	S.S. Monahan	833	A&E	Unknown	SDW
1968	S.S. Mormactern	7,763	Chem.	N.A.	SDW
	S.S. Richardson	7,437	A&C	138	SDW
1969	S.S. Cape Tryon	7,626	A&E	1,145	DU
	S.S. Cape Catoche	6,348	A&E	1,359	DU
	S.S. Cardinal O'Connell	6,431	A&E	2,144	DU
1970	S.S. Frederick E. Williamson	5,245	A&E	478	DU
	S.S. Cape Comfort	6,200	A&E	N.A.	DU
	S.S. Walker D. Hines	6,500	A&E	N.A.	DU
	S.S. David Hughes	5,000	A&E	N.A.	DU
	S.S. LeBaron Russell Briggs	2,664	Chem.	N.A.	SDW

Definitions: A&E=ammunition and explosives; N.A.=not available; DU=Detonated unintentionally; SDW=sunk in deep water; D=detonated; S=sunk at less than 4,000 feet and did not detonate as planned; A&C=ammunition and cylinders contaminated with residues of GB nerve gas.

by finding economic ways of utilizing land disposal. Table 2.6 shows the sharp decrease of radioactive wastes from 1946 up to 1970.

Disposal Methods

The methods employed for sea disposal of wastes consist of primarily transporting the materials aboard vessels or through pipelines. Industrial wastes are mainly discharged in bulk or containers from towed or self-propelled barges. Bulk wastes are usually discharged from tank barges while underway. Containerized wastes can be weighted and sunk or ruptured at the sea surface and sunk. Dredged material is handled routinely by the U. S. Army Corps of Engineers aboard oceangoing hopper dredges. Submarine outfall is a common disposal practice of sewage effluents.

Barges. One of the most common methods of ocean waste disposal is by barge, which can be towed or automated, and the wastes are released in bulk or containers. Table 2.7 illustrates the characteristics of various barges. The bulk wastes can be discharged from a barge in three manners: dumping entire load at once while the barge is anchored; discharge load over a period of time while barge is moving; and discharge from moving barge through a diffuser (Koh, 1971).

The hopper dredge is one type of self-propelled barge which is commonly used by the Corps of Engineers in its dredging practices. Bottom sediments are pumped through drags or underwater pipes into hoppers which are equipped with overflows. The solids are concentrated

TABLE 2.6. Radioactive Wastes: Historical Trends, 1946-1970 (Council on Environmental Quality, 1970)

Year	Number of Containers	Estimated Activity at Time of Disposal (curies)
1946-1960	76,201	93,690
1961	4,087	275
1962	6,120	478
1963	129	9
1964	114	20
1965	24	5
1966	43	105
1967	12	62
1968	0	0
1969	26	26
1970	2	3
Total	86,758	94,673

TABLE 2.7. Barge Characteristics (Clark, et al., 1971)

Capacity (Tons)	Type of Waste	Average Depth of Discharge (feet)	Type	Discharge Characteristics			
				Pipe Size (Inches)	Number Spacing	Towing Speed (Knots)	Discharge Rate (Tons/min)
5,400	Iron-acid	10	Pumped	12	2 @ 50 ft.	8.5	78
	Ore washing mud	10	Gravity	-	2 @ 50 ft.	8.5	
3,200	Iron-acid	10	Pumped	12	2 @ 43 ft.	6.0	16-39
5,000	Chem-Insecticides	10	Gravity	-	-	-	-
1,200	Chlorinated Hydrocarbons	12 below deck	Pumped	8	1	6.0	5
1,100	Chlorinated Hydrocarbons	8	Pumped	4	1	6.0	4
8,000	Philadelphia Digested Sludge	-	Gravity	24	8		267
6,300	NYC Digested Sludge	-	-				210
350	Dredge Spoil	17-20	Gravity		Bottom dump	-	100-200

in hoppers with the finer particles overflowing through troughs in the top of the hoppers. The hoppers can be emptied in three to fifteen minutes depending upon the volume and consistency of the dredged materials (Clark, et al., 1971).

Automated sewage disposal barges are utilized by many cities. New York City transports some of its digested sludge using a 6300-ton self-propelled barge which can handle liquids, acids or suspended matter (Clark, et al., 1971). The dimensions of this barge are 226 feet long, 56 feet wide, and 20 feet deep, and it can discharge its waste in 30 minutes (Smith and Brown, 1971).

Towed barges have various characteristics and are used for disposing of different types of materials. They can be bottom release scows used for dredging operations or specialized tank barges for sewage and industrial sludges, toxic liquids and gases, and pressurized liquids. For example, the construction and demolition debris from the New York area is transported to sea by 3000- to 5000-ton capacity hopper barges that are towed to the offshore disposal site (Council on Environmental Quality, 1970).

According to Creelman (1969), there are three basic configurations of tank barges: single-skin, double-skin, and double-skin with independent cargo spaces. Single-skin barges carry petroleum products. Poisons, acids, and materials requiring heat or insulation utilize double-skinned vessels. The double-skin vessels with cylindrical tank spaces generally transport liquids under pressure.

As stated in Smith and Brown (1971), bulk industrial wastes are most commonly transported to disposal areas in tank barges with double-skinned bottoms. These have capacities from 1,000 to 2,000 short tons, and the discharge rates vary between 4 and 20 tons per minute. The depths at which the wastes are released ranged from six to fifteen feet, and towing speeds of three to six knots are generally utilized during the discharge operations.

Many factors influence the economics of barging. The associated costs are affected by the discharge rate, water depth, barge capacity, and distance to the disposal site. The type of waste materials and the location of disposal also influence the cost. Table 2.8 (Gunnerson, et al., 1970) presents average disposal costs on a dollar per wet ton basis, and these costs are representative of the following geographic areas: Philadelphia, New York City, Elizabeth, New Jersey, Baltimore, and Washington, D.C.

Containerized methods. Radioactive and various toxic industrial wastes are disposed of at sea in containers. The most popular waste container is the 55-gallon steel drum which can be carried to sea on the decks of ships and barges and simply dropped overboard. The drums may be weighted with concrete to insure sinking. For the disposal of radioactive wastes, the Atomic Energy Commission requires a minimum weight of 550 pounds to insure sinking (Smith and Brown, 1971). Containers with certain industrial wastes are ruptured at the water surface. Drums that are not ruptured are expected to sink to the ocean bottom and eventually become covered with sediments before

TABLE 2.8. Reported Costs of Barging Operations in $/Wet Ton (Gunnerson, et al., 1970)

Waste	Total	Pacific	Atlantic	Gulf
Industrial				
(a) bulk	1.70	1.00	1.80	2.30
(b) containerized	24.00	53.00	7.73	28.00
Refuse and garbage	15.00	15.00	----	----
Sewage sludge	1.00	----	(.8-1.2)	----

the drum deteriorates, but there are known cases of drums found floating in areas far from the disposal sites.

Submarine outfalls. Ocean disposal of sewage wastes is typically accomplished by submarine outfalls that consist of a long section of pipe to transport the waste from shore. A diffuser section is usually included to dilute the waste with wastewater. At the end of the outfall, treated or untreated wastewater is released in a stream or jetted through a manifold or multiple-port diffuser. Here the sewage mixes with surrounding seawater, and the mixture sometimes rises to the surface and drifts in accordance with the prevailing ocean currents (Metcalf and Eddy, 1972).

The design of an outfall should meet the standards of the receiving water. Bacterial, floatable material, nutrient, and toxicity requirements have to be taken into consideration in the design and selection of an outfall. Outfall sizing is determined by the velocity, head loss, structural considerations, and economics of the situation. Velocities of two to three feet per second at average flow are normally recommended to avoid excessive head loss (Metcalf and Eddy, 1972).

In general, outfalls are trenched, backfilled and ballasted throughout the length of the pipeline because of movements of the bottom. Five to eight feet of cover over submerged pipelines in channels used by deep-draft vessels is required by the U. S. Army Corps of Engineers (Chemical Engineering Staff, 1971).

Costs of submarine outfalls vary widely because of differences in surf and bottom conditions. The most expensive part of an outfall (Figure 2.2) is in the surf zone where the most movement of beach material, wave erosion, and storm forces occurs, and therefore, the pipe has to be buried for its own protection. The average cost of the structure depends upon the length of the outfall and the ratio of the offshore to onshore sections. Table 2.9 shows reasonable estimates of the average construction costs per unit length of outfall for the sizes of outfall suitable for three ranges of flows; these values are in the middle ranges of construction costs (adjusted to 1973 prices) for outfalls built along the Pacific coast during the past twenty years (Pearson, 1975).

Bargman (1975) described the outfalls used by the Hyperion Treatment Plant in Los Angeles. The mixed treated effluents are discharged five miles into water 200 feet deep, and the solids are digested, screened and discharged through conduit seven miles from shore. The effluent outfall, made of reinforced concrete, is 12 feet in diameter with two diffuser legs each 4000 feet long. There are 84 discharge ports in each leg. The residual solids outfall has a 22-inch outside diameter and is constructed of a steel pipe with a gummite coating over coal tar and with a cement-lined interior.

The Orange County Sanitary District utilizes a 120-inch diameter outfall to release 140 million gallons per day of effluent with a total dissolved solids content of approximately 2600 parts per

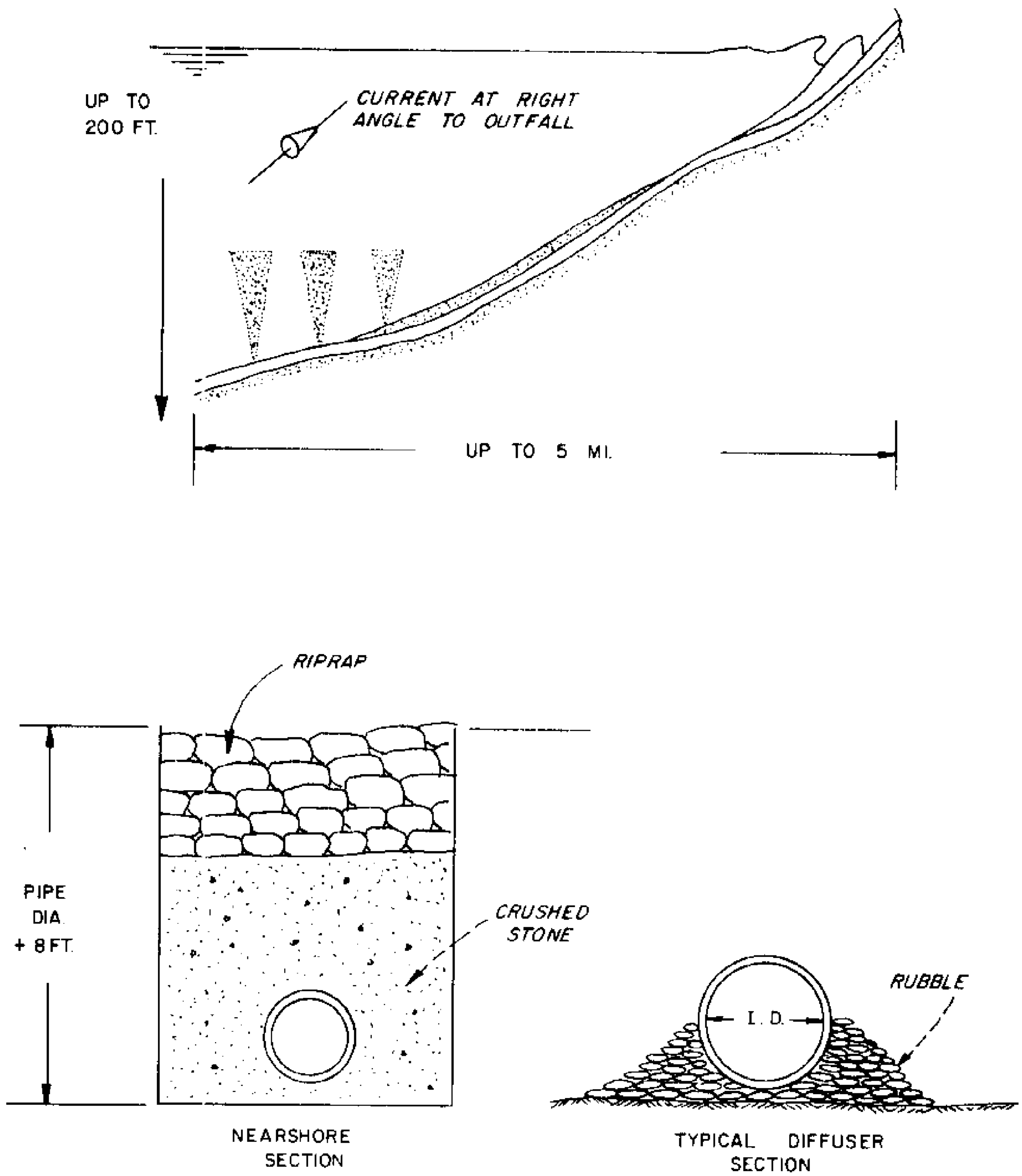

FIGURE 2.2. SUBMARINE OUTFALL CONFIGURATION
(CHEMICAL ENGINEERING, 1971)

TABLE 2.9. Estimated Unit Costs of Submarine Outfalls California Construction Practice in 1973 (Pearson, 1975)

Design Flow		Sewer Size		Construction Cost
m^3/day	(mgd)	cm	(in.)	\$/m
3,780	(1)	15	(6)	330
37,800	(10)	61	(24)	1,395
378,000	(100)	194	(76)	2,720

million. The waste is discharged into an average depth of 190 feet through a 6000-foot diffuser section with 500 ports spaced at 24-foot centers along each side (Heckroth, 1973).

CHASE. From 1964 to 1970, the U. S. Navy utilized the CHASE ("Cut Holes and Sink Em") program for the ocean disposal of outdated explosives and chemical munitions (Smith and Brown, 1971). Surplus World War II cargo ships were stripped of equipment and machinery, and then they were filled with the wastes and towed to sea. These ships were sunk by flooding and the cargo was detonated; although one ship scuttled off the coast of Alaska failed to detonate due to its drifting into waters too shallow to set off the detonators. The costs for the CHASE disposal operations from 1964 through 1968 ranged from $76,482 to $162,843 (Smith and Brown, 1971).

Indirect discharges. Waste materials reach the ocean by means other than direct disposal. Rivers flowing from inland areas carry both natural and man-made pollutants to the ocean. The atmosphere transports contaminants such as pesticides and exhaust residues of transportation to the sea. Many materials are discharged accidentally as the result of errors and collisions, particularly during transportation. Accidents such as oil and hazardous material spills introduce an entire class of toxic compounds to the marine environment. There are also incidents of authorized or illegal tank washings taking place. During offshore drilling and mining activities, salts, oils and other materials are released in the sea.

Natural processes also contribute materials to the ocean that would be called pollutants if man put them there (Bascom, 1974). Streams add fresh water which can be damaging to some marine organisms such as coral, and they also transport contaminants and sediments washed by rain from land. Even the natural occurrence of volcanic eruptions adds large quantities of pollutants. Oil seeping from the sea bottom contributes polluting compounds to the marine environment.

Transport Mechanisms of Waste Materials

Three general factors determine the transport and dispersion of waste disposed of in the ocean (Clark, et al., 1971). These are:

(1) What is introduced - its physical, biological, and chemical properties.

(2) Where it is introduced - its position with respect to local ambient-density and velocity distributions.

(3) How it is introduced - its residual buoyancy and momentum.

Physical factors affecting transport and dispersion. Predominant physical oceanographic factors affect material transport near the sea surface, in the water column, and near the seabed (Table 2.10). Surface waves are important for the movement of materials in the surface layer and on the central and inner shelf. Internal waves, breaking or shoaling, play a role in the erosion or deposition of bottom

TABLE 2.10. Principal Mechanisms Affecting Transport and Dispersion (National Academy of Sciences, 1976)

Physical Characteristics \ Factors Influencing Motion	Surface Waves	Internal Waves	Tidal and Inertial Currents	Subtidal Currents	Seasonal Current Variability	Bathymetry	Meteorological	Hydrography
SURFACE								
Float as discrete aggregate	x		x	x	x		x	
Form slicks	x		x	x	x		x	
FLUID INTERIOR								
Density near that of water			x	x	x	x	x	x
Density varies with respect to water			x				x	x
NEAR BOTTOM								
Move continuously	x	x	x	x		x	x	
Move rarely	x	x	x	x	x	x	x	

materials in regions with large gradients in the density field. All three transport modes are influenced by ocean currents at varying degrees.

Diffusion coefficients. Diffusion phenomena are important to dispersal of wastes. Koh and Chang (1973) distinguished between two diffusion coefficients, horizontal and vertical for turbulent transport. The vertical coefficient is quite smaller than the horizontal because it is affected by density stratifications in the water column. The vertical coefficient has its maximum value at the surface and decreases with depth. These values vary from 1×10^2 to 3.0×10^2 cm^2/sec whereas the horizontal coefficients range from 5×10^2 to 4×10^8 cm^2/sec. The horizontal and vertical diffusion coefficients are defined by the following equations:

$$K_x = - \frac{\overline{u'c'}}{\frac{\partial \bar{c}}{\partial x}} + Dx$$

$$K_y = - \frac{\overline{v'c'}}{\frac{\partial \bar{c}}{\partial y}} + D_y$$

$$K_z = - \frac{\overline{w'c'}}{\frac{\partial \bar{c}}{\partial z}} + D_z$$

where K_x and K_y are horizontal diffusion coefficients, K_z is the vertical diffusion coefficient, $\overline{-u'c'}$, $\overline{-v'c'}$, $\overline{-w'c'}$ are turbulent transport quantities in x, y, z directions, $\bar{c}$ is the mean concentration of the transported material, and D_x, D_y, D_z are the molecule diffusion coefficients.

Waste dispersion studies. Various studies were conducted to determine the fate of materials disposed of in the ocean. Ketchum and Ford (1952) of the Woods Hole Oceanographic Institute carried out an early study of dispersion of waste materials dumped from a barge in 1948 and 1950. The waste consisted of 10 percent $FeSO_4$ and 8.5 percent H_2SO_4 in water and was pumped from the barge at rates of 32,000 to 78,000 pounds per minute while the barge was towed at a speed of six knots. The distribution of iron concentration was measured as a function of time and the mixing coefficient was calculated. The mixing coefficients showed a tendency to increase with increasing time, and thus with the dimensions of the mixing field, which also increased with time.

D. W. Hood conducted investigations of ocean disposal of caprolactum wastes from a petrochemical plant at Texas A&M University (Hood, 1961). The barge was towed at five knots and contained 3,141,500 pounds of waste with 250 pounds of 25 percent Rhodamine B dye added as a tracer. The dilution rates, coefficients and ratios were lower than the constants determined by Ketchum and Ford. At a speed of five knots the initial concentration in the barge was diluted by a factor of 2840 to one over a period of one minute. A second study carried out by Hood produced similar results.

Waste dispersion studies were carried out at Texas A&M University for industries located along the Gulf of Mexico. The dispersion of liquid wastes from three DuPont petrochemical plants was investigated May, 1973 (Ball, et al., 1973). The waste was discharged from a 4,600 ton barge at 35,000 pounds per minute at a speed of five knots. The initial dilution factor calculated for this study was 2270 to one for a period of one minute.

A second dispersion study was conducted for the GAF Corporation in July, 1973 (Reynolds, et al., 1974). The scope of the work was similar to the previous study. The results of this investigation differed in that there was a definite change in the dilution rate at approximately eight minutes. It appeared that the injection of a waste into a turbulent wake of a barge caused an immediate, large-scale dilution to occur. After eight minutes, the barge turbulence subsided and the waste continued to be diluted, although at a slower rate, by the action of oceanic factors.

Effects of Waste Disposal on Marine Life

Marine life can be directly affected by waste materials that act as pollutants. Four ways of pollution occur through toxicity, oxygen depletion, biostimulation, and habitat changes (Council on Environmental Quality, 1970). The four categories are interrelated in that these effects can cause other pollution problems. For example, toxicity, oxygen depletion, and biostimulation can all cause changes in habitats. Also, each of these deleterious effects can lead to human impacts.

Toxicity. The effects of toxic wastes on marine plants and animals are classified as acute or chronic toxicity. The acute (lethal) level of a compound is the concentration which results in death to a significant number of a given species within a specified exposure period. The chronic (sublethal) level of a compound interferes or alters the life functions of an organism. Chronic effects do not immediately result in death but may eventually lead to death. Sublethal effects include interferences with biological processes such as growth, physiology or behavior, or reduction of breeding success (Cole, 1973).

The acute toxicities of substances are determined by various experimental methods. Some of the more common terms used in expressing toxicity are TLm (median lethal concentration), LD_{50} (lethal dose fifty), LC_{50} (lethal concentration fifty), EC_{50} (median effective concentration), and ED_{50} (therapeutically effective dose). The median lethal concentration produces 50 percent mortality in exposed organisms in 24, 48 or 96 hours. The lethal dose fifty is the weight of toxicant per body weight that results in 50 percent mortality and is statistically determined, while the lethal concentration fifty is the amount of toxicant which produces 50 percent mortality. The median effective concentration and the therapeutically effective dose both produce a designated effect in 50 percent of the organisms, but the therapeutically effective dose differs in that its effect is reversible.

Much data is available on the acute toxicities of many compounds, particularly pesticides. This discussion will focus on the effects of some of the more prominent compounds that are candidates for ocean disposal. Pesticides and other toxic materials are known to cause fish kills in freshwater systems, and they are assumed to produce similar effects in marine waters (Interstate Electronics Corporation, 1973).

Eisler (1969) reported on the acute toxicity of DDT in values of TLm 24 (parts per million) for various marine animals: sand shrimp, 0.003 ppm; hermit crab, 0.007 ppm; and grass shrimp, 0.012 ppm. Heptachlor at 0.003 ppm (TLm 48) and malathion at 0.55 ppm (TLm 48) produce mortality in mullet (Butler, 1963). A dose of 0.10 ppm of Aroclor 1254 is a lethal concentration in 48 hours to juvenile pink shrimp (Gustafson, 1970).

Other industrial chemicals produce lethal effects, but higher levels of these are required for death. A TLm 48 value of 42.5 ppm of sulfuric acid for pink shrimp was derived by Portmann and Wilson (1971) who also found the TLm 48 of phenol for pink shrimp to be 17.5 ppm. Sodium hydroxide is lethal to brown shrimp at 33 to 100 ppm (Portmann and Wilson, 1971). Clemens and Sneed (1959) determined that 69 ppm of methanol is lethal to fingerling channel catfish.

Chronic toxicities of various compounds produce physiological changes in marine organisms. In California, in the vicinity of a sewer effluent, Young (1964) found many physical abnormalities. A condition of exophthalmia, abnormal protrusion of the eyeball, was observed in spotfin croaker and white seabass. Dover sole and white seabass were found to have "cancerous" lesions, while the white croaker had tumor-like sores about the mouth. White croaker and dover sole in the vicinity of a sewage outfall off the coast of California suffer from fin erosion diseases. This is a non-systemic disorder in sole initiated by irritation to the protective mucous of fins. In a study by Young and Pearce (1975), the lobster and rock crabs collected in or near the New York Bight showed various pathological conditions of the shell and gills.

Behavior reactions are also caused by chronic levels of waste materials. Crabs feeding on contaminated material containing chlorinated hydrocarbons showed impairment of escape reaction (Krebs, et al., 1974). Fin fish and grass shrimp exhibited avoidance of Aroclor 1254 (polychlorobiphenyl) contaminated water (Hansen, et al., 1974).

Growth can be inhibited by the presence of certain compounds such as hydrocarbons and biphenyls. Menzel, et al. (1970) experimentally proved that photosynthesis and growth in cultures of four species of marine phytoplankton were affected by three chlorinated hydrocarbons (DDT, dieldrin and endrin). Aroclor 1242 caused reduction in growth, chlorophyll index, and RNA synthesis of a marine diatom (Keil, et al., 1971). At 32 ppm of dieldrin, growth stopped in the diatom *Navicula seminulum* (Cairns, 1968).

The breeding success of organisms can be hampered when exposed to sublethal doses of compounds. Toxicants can reduce a species by not allowing it to reach adulthood. Oyster eggs exposed to pesticides hatch, but the resulting larvae do not survive at a given concentration (Davis and Hidu, 1969). Immobility in marine organisms can prevent them from successfully mating. Butler (1963) found that phytoplankton productivity decreased 84.8 percent when exposed to 1 ppm of dieldrin for four hours.

The bioaccumulation and biomagnification of a compound within an organism can have far-reaching effects upon the marine ecosystem. Pesticides and heavy metals are known to concentrate in organisms at thousands of times their original concentrations. Compounds which accumulate within organisms may not prove to be toxic to them, but these may show up in subsequent generations or in higher forms of animals that feed upon the lower animals in the food chain. Effects of biomagnification can even affect man if he consumes contaminated marine organsims.

Oxygen depletion. Dissolved oxygen is a water quality property that sustains marine life. Oxygen is also necessary for the biological degradation of organic materials. When large quantities of organics are disposed of in the ocean, they tend to use up the oxygen which is required to support populations of aerobic organisms. The reduction in dissolved oxygen can result in the development of anaerobic conditions with associated water odor problems, and the destruction of aerobic marine life.

The major sources of dissolved oxygen in seawater are through atmospheric reaeration and photosynthesis of chlorophyll-bearing plants. Coastal waters normally have a dissolved oxygen concentration range of 4 to 14 milligrams per liter (Ludwig and Storrs, 1970). The concentration will vary seasonally due to temperature and with depth. The lower concentrations are usually found in deeper waters where the oxygen supply is limited by distance from surface and by lack of photosynthesis.

Sewage wastes, dredged material, and industrial wastes disposed of in the ocean can cause oxygen depletion if discharged in amounts that use up the dissolved oxygen in the bacterial and chemical oxidation of the organics. The depletion of oxygen can alter the diversity and life functions of organisms, reduce organism populations, and cause the flourishing of anaerobic bacteria.

According to Torpey (1967) there are three general steps in the sequence of oxygen depletion in most waters.

(1) When the oxygen demand of the pollutants reaches 20 pounds of oxygen per day per acre, instability develops and the level of oxygen drops.

(2) When the level of pollution loading requires 20 to 132 pounds of oxygen per day per acre, the oxygen content remains essentially constant at 25 to 50 percent saturation.

(3) When the demand of high pollution loading levels exceeds 132 pounds of oxygen per day per acre, the oxygen supply is exhausted and anaerobic conditions develop.

Generally, there is a 2 to 13 parts per million difference in the oxygen content level between the surface and bottom water of the New York Bight. Between July and October when the thermocline limits natural mixing, the most severe oxygen depletion of the bottom water occurs. Water in the disposal area contained three parts per million less dissolved oxygen than water at the same depth outside the area. In the summer, the oxygen level in the bottom waters of the sludge dump often reaches two parts per million, a level insufficient to support marine life (Pearce, 1969).

Oxygen depletion causes organisms to die and anaerobic bacteria produce hydrogen sulfide and methane gas which cause odor problems. Sediments collected in areas of oxygen depletion are blank and malodorous. These are characteristics of an environment devoid of oxygen and highly reducing. Hydrogen sulfide produced with the waste deposits inhibits colonization by non-tolerant infauna (Pratt, et al., 1973).

Biostimulation. This phenomenon is the accelerated fertilization of plant life caused by excessive amount of nutrients, particularly nitrates and phosphates. Sewage wastes disposed of in the ocean are very rich in these nutrients. The dense growths of phytoplankton, if not utilized by grazing organisms, may cause oxygen depletion and aesthetic degradation of localized areas (National Academy of Sciences, 1971).

Eutrophication, enrichment of nutrients, in seawater can lead to excessive growth of undesirable types of algae and to formation of large blooms of free-floating phytoplanktonic organisms which may color the water in shades of green, brown, or red (Baalsrud, 1975). Increased blooming of the toxic marine dinoflagellates such as *Gonyaulax* is undesirable due to toxin within this organism (Ludwig and Storrs, 1970). These dinoflagellates are ingested by molluscs which can concentrate the toxins to levels harmful to humans. This phenomenon which is termed the "red tide" is also aesthetically unappealing.

Excessive blooms of algae can indirectly change the nature of bottom sediments which can lead to alterations of whole communities of bottom organisms. For example, an algal mud can cover the sand bottom which supports surf clams and this can lead to extinction of the species in that area. Greatly increased concentrations of organic matter have been found in sediments adjacent to disposal areas (Council on Environmental Quality, 1970).

A thick mat of algae sustained by nutrients can suffocate life beneath it. Light cannot pass through the algal growth, and therefore, photosynthesis cannot take place. Also, the decomposition of algae utilizes the oxygen necessary to support marine life. This oxygen depletion leads to reduced numbers of organisms.

Habitat changes. A habitat may be defined as the place where a plant or animal normally lives and grows. Existing evidence indicates that waste disposal can drastically alter marine environments. A change in the physical environment represents a stress factor which inhibits the evolution of diversified communities or results in the retrogression of stable diversified communities to less diversity and stability (U.S. Department of Commerce, 1972).

Ecological changes are brought by the ocean disposal of dredged material, sewage wastes and toxic wastes which bury or render the substrate unlivable. Materials such as dredged material and sewage sludge can cause bottom sediment buildup. The effects of rapid local buildup of sediment include destruction of spawning areas, reduction in food supplies and vegetational cover, trapping of organic matter resulting in anaerobic bottom conditions, and the absorption or adsorption of organic matter (Smith and Brown, 1971).

As the result of alterations in an ecosystem, sensitive organisms are killed or unable to compete, leaving the more resistant species. This ecological disturbance has occurred in the Pacific Ocean where the "crown-of-thorns" starfish, *Acanthaster planci*, is rapidly reproducing and eating the coral at a rate faster than it can multiply (Newman, 1970). Predators of the starfish have been exterminated, and the blame has been placed on the sediment buildup resulting from dredging and blasting and the widespread use of pesticides. It has also been speculated that the pesticides have impeded the coral's ability to reproduce and act as a predator of the starfish.

Sewage outfalls off the coast of southern California have been blamed for the destruction of the forests of giant kelp by the bottom-hugging sea urchin (Marx, 1967). The urchins were thought to feed on sewage particles and scum spawned by the sewage and to reproduce at fast rates. The urchins grazed upon the kelp beds and deprived the kelp in the area of any chance to survive.

Destruction of organisms such as coral and giant kelp also causes decline of other organisms. Both kelp and coral act as habitats for other forms of marine life. Alterations to the marine environment can cause a chain reaction of deleterious effects which present economic and ecological losses.

Effects of Waste Disposal on Humans

These effects have been divided into categories of health, asthetics, and economics. These problems are brought about by the direct effects of wastes on marine organisms. When effects of wastes occur in one category, impacts are also felt within the realms of the other categories of human effects.

Health. The ocean disposal of sewage wastes and polluted dredged materials can pose human health hazards. These waste materials are potential carriers of bacterial and viral pathogens from human and other animal intestinal tracts (U.S. Department of Commerce, 1974). Coliform bacteria are used as indicators of the possible presence of pathogens. The Environmental Protection Agency gives permissible coliform levels of 10,000 per 100 milliliters and fecal coliform levels of 2,000 per 100 milliliters for bathing. The desirable criteria levels are given as 100 per 100 milliliters and 20 per 100 milliliters for fecal coliform groups (Pararas-Carayannis, 1973).

Sewage wastes are a common source of enteric pathogens. Table 2.11 lists the principal pathogenic organisms which may be present and the infections caused by them. The excretion of enteric viruses by apparently healthy individuals is largely confined to children under age 15. The enteric virus density in feces was computed on a per capita basis to be about 200 virus units per gram of feces (Scarpino, 1975).

TABLE 2.11. Enteric Pathogens in Sewage
(Gameson and Pike, 1970)

	Infection
Bacteria:	
Escherichia coli	Some strains cause enteritis in infants
Salmonella	Typhoid and paratyphoid fevers, food poisoning, gastro-enteritis
Shigella	Bacillary dysentery
Clostridium	Food poisoning, gas gangrene
Staphylococcus aureus	Pyogenic skin and wound infections, food poisoning
Mycobacterium tuberculosis	Tuberculosis (not essentially enteric)
Leptospira	Weil's disease, jaundice
Viruses:	
Poliovirus	Poliomyelitis
Infectious hepatitis virus	Hepatitis, jaundice
Adenoviruses	Conjunctivitis, pharyngitis
Coxsackie viruses A and B, ECHO-viruses, reoviruses	Enteritis, fever, rashes, attack of central nervous system
Protozoa:	
Entamoeba histolytica	Amoebic dysentery
Metazoa:	
Nematode ova	Roundworm and threadworm infestations
Cestode ova	Tapeworm infestation; pork tapeworm ova (*Taenia solium*) can re-infest man

Shellfish have been found to be polluted with enteric organisms because they are filter feeders. During filtration, 5 to 30 percent of suspended bacteria are retained and these with other particles pass through the alimentary tract (Pike and Gameson, 1970). Liu, et al. (1966), who studied the fate of poliovirus in northern quahaugs, found several species of shellfish capable of accumulating significant amounts of virus very fast in digestive diverticula and hemolymph. Four outbreaks of hepatitis involving about 900 cases of illness in the United States were traced back to consumption of raw quahaugs and hard clams (Mason and McLean, 1962).

Parasitological problems should also be considered in connection with the ocean disposal of municipal wastes. Zooparasites can gain entrance into the human body by contaminated food. Human parasites released with wastes can infect marine animals. Man can consume the infected animals and the parasites are transmitted back to him (Foyn, 1971).

Marine organisms consumed by man are contaminated by wastes other than sewage wastes. Pesticides which are known to contain quantities of carcinogenics are accumulated by fish and shellfish. It has not been proven, only speculated, that cancer in humans can be caused by consumption of contaminated seafood. Certain heavy metals are also known to accumulate in marine organisms. The contamination of seafood by heavy metals can lead to severe neurological disorders and even death in man. The case of the "Minamata disease" in Japan is an example of a human health hazard caused by the bioaccumulation of methyl mercury in fish.

Aesthetics. The loss of the aesthetic characteristics of beauty and cleanliness have major effects on recreational resources (Ludwig, 1975). Many people of the United States enjoy the recreation and beauty of the coastal waters. The ocean disposal of certain wastes threatens to destroy the amenity values of the coast.

Floatables, which are a major aesthetic threat, are materials contained in wastes which rise, sooner or later, to the ocean surface. These materials in the forms of oils, greases, waxes, tars, and floating debris also can create surface slicks. Floatables are subject to wind transport. The wastes may drift to shore where they pose public health and nuisance problems. The presence of oil, tar or dead fish are common sights on the nation's coastal waters and beaches.

Economics. The impacts of ocean pollution greatly affect the economy of this nation. The greatest loss to man's pocketbook is the destruction of fisheries normally harvested for commercial purposes. Another loss that can be incurred is the damage to recreational areas. Both fishing and recreation on this nation's coasts provide livelihoods for many people.

An obvious loss is the closure of fishing areas due to contamination from bacteria, pesticides, and metals. The Food and Drug Administration can declare a harvesting area unfit for seafood harvesting, and man is no longer able to extract seafood species from this area until safe levels are returned.

An estimated 20 percent of United States' shellfish beds, valued at $63 million, have been closed due to damaging concentrations (Lacy and Roy, 1975). The potential value of United States' shellfish catch for the year 1969 was estimated to be $320 million, but the actual value was only $257 million due to a total catch of 729 million pounds which was 181 million pounds less than the potential catch (Council on Environmental Quality, 1970).

Smaller harvests of seafood are also caused by wastes that kill certain marine species. Since life in the ocean is connected by a food chain, death of even the smallest organisms can result in the extermination of larger species commercially harvested.

The tainting and discoloration of seafood can have a depressing effect on sales and prices, although the food is not unsafe for human consumption. Substances such as oil, phenol and cresols are known to taint fish by leaving obvious odors and tastes which render the fish unsaleable.

When recreational areas are polluted by ocean disposal, man has to pay the cost of cleaning up the areas. Floatables which litter the coastal waters threaten to destroy the amenity values. People will not spend their money in places visibly polluted or known to be unsafe to their health.

Legislation and Regulations

Federal legislation relating to waste disposal in the marine environment began with the Rivers and Harbors Act of 1899 which made it unlawful to discharge refuse materials of any kind into the navigable waters of the United States. The Secretary of the Army was given authorization to administer this Act through the Corps of Engineers. Although the 1899 Act was originally intended to apply only to debris that might obstruct navigation, later interpretations of this law included virtually all materials, including oil, industrial wastes, sewage, and garbage. The Corps of Engineers was responsible for granting anyone permission to dispose of wastes in the marine environment. Their duties also included governing the transportation and disposal of wastes into any navigable waters. The disposal sites were established by the Corps of Engineers as provided for in the Rivers and Harbors Act of 1905. The activities of the Corps helped to significantly reduce pollution of the waters, but this was not adequate enough to protect marine life. These inadequate regulatory procedures and a greater environmental awareness resulted in the passage of two important water pollution laws in 1972: The Federal Water Pollution Control Act Amendments of 1972 (Public Law 92-500) and The Marine Protection, Research and Sanctuaries Act of 1972 (Public Law 92-532).

The resultant legislation provided for control of both pipe discharges (Public Law 92-500) and materials discharged from vessels (Public Law 92-532). A common set of regulations as shown in Figure 2.3 applies to the administration of both programs. Two parts of this regulation which consider some of the scientific aspects are shown in greater detail in Figure 2.3 .

LEGISLATION

Federal Water Pollution Control Act Amendments of 1972
PL 92-500

Title I	Research and related programs
Title II	Grants for construction of treatment works
Title III	Standards and enforcement
Title IV	Permits and licenses
Title V	General provisions

Marine Protection, Research, and Sanctuaries Act of 1972
PL 92-532

Title I	Ocean Dumping
Title II	Comprehensive Research on Ocean Dumping
Title III	Marine Sanctuaries

REGULATIONS

Subchapter H Ocean Dumping

Part 200	General
Part 221	Applications
Part 222	Actions on applications
Part 223	Contents of permits
Part 224	Records
Part 225	Corps of Engineers Permits
Part 226	Enforcement
Part 227	Criteria for the evaluation of permit applications
Part 228	Management of disposal sites
Part 229	General Permits

PART 227 CRITERIA FOR THE EVALUATION OF PERMIT APPLICATIONS

1. General grounds for issuance
2. Prohibited Acts
3. Strictly regulated dumping
4. Implementation plan requirements for interim permits
5. Less strictly regulated dumping and disposal acts
6. Disposal of dredged material
7. Definitions
8. Amendment of criteria

PART 228 MANAGEMENT OF DISPOSAL SITES

1. Definitions
2. Disposal Site Management
3. Procedures for designation of site
4. Criteria for the selection of site
5. Regulation of disposal site use
6. Delegation of management authority, for interim sites

APPENDICES

A. Baseline survey requirements
B. Monitoring survey requirements

FIGURE 2.3. OCEAN DISPOSAL LEGISLATION & REGULATIONS
(National Academy of Sciences, 1976)

Public Law 92-500. The enactment of the Federal Water Pollution Control Act Amendments of 1972 on October 18, 1972 initiated a national program to prevent, reduce and eliminate water pollution in all of the nation's waters, including the oceans (92nd Congress of the United States, 1972a). Section 101.(a) of the Act states the objective: "to restore and maintain the chemical, physical, and biological integrity of the nation's waters."

The law proclaims several general goals for the United States:

(1) the attainment, by July 1, 1983, wherever possible, of waters clean enough for recreational uses and the propagation of fish, shellfish, wildlife;

(2) by 1985, zero discharge of pollutants into the nation's waters;

(3) the prohibition of the discharge of toxic pollutants in toxic amounts; and

(4) the development and implementation of a major research program to develop the technology necessary to eliminate the discharge of pollutants into the navigable waters, waters of the contiguous zone, and the oceans.

The primary responsibility of carrying out the provisions of the law lies with the states, but they have to do so within the framework of the program. If the states do not or cannot fulfill their obligations under the law, the United States Environmental Protection Agency has the power to take action.

The law states that all sewage treatment plants must provide secondary treatment by mid-1977. This provision will affect the discharge of materials to the ocean. Presently in some areas, raw and primary effluents are being discharged from vessels and outfalls. Secondary treatment will prevent the disposal of these effluents, but as a result of this further treatment, more sewage sludge will have to be disposed of somewhere.

Sections 402 and 403 of this law provide for the issuance of permits for outfall discharges into the ocean. Section 402 ("National Pollutant Discharge Elimination System") authorizes a state with the capability to issue permits within its jurisdiction. The permits have to be in compliance with the requirements of the law. Section 403, entitled "Ocean Discharge Criteria," requires the development of specific guidelines to be met before a permit is issued: the effects of disposal of pollutants on human health, marine life, aesthetic, recreation, and economic values. Another guideline requires the investigation of alternate methods or recycling of pollutants. If insufficient information exists to make a reasonable decision on any of the established criteria, a permit is to be denied.

Public Law 92-532. The passage of the "Marine Protection, Research, and Sanctuaries Act of 1972" on October 23, 1972, set up a national policy for the ocean disposal of wastes from vessels. Section 2 of the Act states the "Finding, Policy, and Purpose" in the following quote (92nd Congress of the United States, 1972b):

> Sec. 2. (a) Unregulated dumping of material into ocean waters endangers human health, welfare, and amenities, and the marine environment, ecological systems, and economic potentialities.
>
> (b) The Congress declares that it is the policy of the United States to regulate the dumping of all types of materials into ocean waters and to prevent or strictly limit the dumping into ocean waters of any material which would adversely affect human health, welfare, or amenities, or the marine environment, ecological systems, or economic potentialities.
>
> To this end, it is the purpose of this Act to regulate the transportation of material from the United States for dumping into ocean waters, and the dumping of material, transported from outside the United States, if the dumping occurs in ocean waters over which the United States has jurisdiction or over which it may exercise control, under accepted principles of international law, in order to protect its territory or territorial sea.

Title I ("Ocean Dumping") states the major provisions of the law (U.S. Environmental Protection Agency, 1973). Banned from disposal into the ocean are a group labeled as prohibited materials: biological, chemical or radiological warfare agents, high-level radioactive wastes, and persistent, inert synthetic or natural floating materials. Also, prohibited are materials insufficiently described in terms of their physical, chemical, or biological properties to permit evaluation of their impact on marine ecosystems. The legislation also restricts the discharge of a variety of toxic wastes such as chlorinated hydrocarbons, mercury, cadmium, and oils. Table 2.12

TABLE 2.12. Ocean Dumping Criteria
(Cox, 1975)

Absolutely prohibited materials

Biological, chemical or radiological warfare agents
High-level radioactive wastes
Persistent, inert synthetic or natural floating materials

Materials prohibited in other than trace quantities

Mercury:	solid phase less than 0.75 mg/kg
	liquid phase less than 1.5 mg/kg
Cadmium:	solid phase less than 0.6 mg/kg
	liquid phase less than 3.0 mg/kg
Organohalogens:	less than 1% of a TLm on appropriate indigenous species
Oils and greases:	will not produce a visible sheen on the water in a 1/100 dilution

Strictly regulated materials (materials requiring special care)

Elements, ions and compounds of: arsenic, beryllium, chromium, copper, lead, nickel, selenium, vanadium and zinc.

Organosilicon compounds

Inorganic processing wastes including: cyanides, chlorides, fluorides, and titanium dioxide wastes

Petrochemicals, organic chemicals and organic processing wastes including: aliphatic solvents, amines, detergents, phenols, phthalate esters, plastics, plastic intermediates and by-products and polycyclic aromatics

Biocides not elsewhere prohibited including: carbamate compounds, herbicides, insecticides, and organophosphorus compounds

Oxygen-consuming or biodegradable organic matter

Radioactive wastes not otherwise prohibited

Materials on the toxic or hazardous substances list

Immiscible materials including: gasoline, carbon disulfide and toluene

TABLE 2.12. (Continued)

<u>Hazards to navigation</u>
<u>Large quantities of materials</u>
<u>Acids and alkalis</u>
<u>Containerized wastes</u>
<u>Materials containing living organisms</u>

presents in summary form Part 227.2 (prohibited acts) and Part 227.3 (strictly regulated dumping) of the "Final Regulations and Criteria." The criteria also apply to ocean outfalls.

The U. S. Environmental Protection Agency through its administrator is delegated the overall responsibility for management of the law. Three other federal agencies are obligated to share responsibilities in carrying out this program: the U.S. Army Corps of Engineers, the Department of Commerce through the National Oceanic and Atmospheric Administration and the U. S. Coast Guard.

Under this law, the Environmental Protection Agency had to establish criteria for ocean disposal. This agency designated the ocean disposal sites and was responsible for preparing environmental impact statements on the sites. Permits for ocean dumping of all materials except dredged substances are issued by the Environmental Protection Agency.

The Corps of Engineers is responsible for all dredged material permit activity. The issuance of permits and selection of disposal sites are subject to review by the Environmental Protection Agency. The Corps will allow the disposal of dredged material, unless there is evidence that the proposed disposal will have an adverse affect on municipal water supplies, shellfish beds, wildlife, fisheries, or recreational areas.

The Coast Guard's duty is to monitor the actual disposal operations and see that they are carried out as specified by the permits. Violations of any permit are reported to the Environmental Protection Agency who in turn assesses penalties.

The Department of Commerce through the National Oceanic and Atmospheric Administration as specified under Title II of the Act is to carry out a comprehensive program of research and monitoring to determine the long-range effects of ocean disposal. The findings of this program are to be reported at least annually to the Congress. The research is aimed at reducing or eliminating the practice of ocean disposal. Title III allows for the establishment of marine sanctuaries by the Secretary of Commerce, through the National Oceanic and Atmospheric Administration, with concurrence of various government agencies.

Permit operations. The Marine Protection, Research and Sanctuaries Act of 1972 (Public Law 92-532) stipulates that no one may transport by vessel any materials destined for ocean disposal without a permit from the regional Environmental Protection Agency and Corps of Engineers. Environmental Protection Agency permits cover all materials to be discharged from vessels, except dredged materials which are under the authority of the Corps.

In evaluating permit applications, both agencies must consider a set of general criteria (U. S. Environmental Protection Agency, 1975)

1. the need for proposed dumping;
2. effect of dumping on the marine environment;
3. social and economic considerations including effects on health and welfare, fishery resources, recreational values, etc.;

4. alternate means of disposal, and

5. feasibility of dumping beyond the continental shelf.

The same guidelines apply to issuance of permits for outfall discharges into the ocean as stated in Sections 402 and 403 of the Federal Water Pollution Control Act Amendments of 1972.

Permits issued by the Environmental Protection Agency follow a set procedure for each application (Figure 2.4). Application forms with all the necessary information are submitted to the regional Environmental Protection Agency office where the proposed disposal is to take place. The Environmental Protection Agency reviews the application, gives public notice and allows the opportunity for a public hearing before the issuance of any permit.

Under the Environmental Protection Agency's permitting program, four types of ocean dumping permits are issued: general, special, emergency, interim, and research. A general permit allows the disposal of galley waste from ships and other non-toxic materials disposed of in small volumes. This permit also covers burial at sea. A special permit is issued for the disposal of materials not covered by a general permit, but the materials have to be within the criteria as stated within the law. A special permit has a fixed expiration date (no later than three years from issuance), but it may be renewed. The ocean disposal of prohibited wastes for which there is no other feasible means of disposal is covered by an emergency permit. This type of permit cannot be renewed. An interim permit covers the disposal of materials exceeding the permissible criteria. This permit

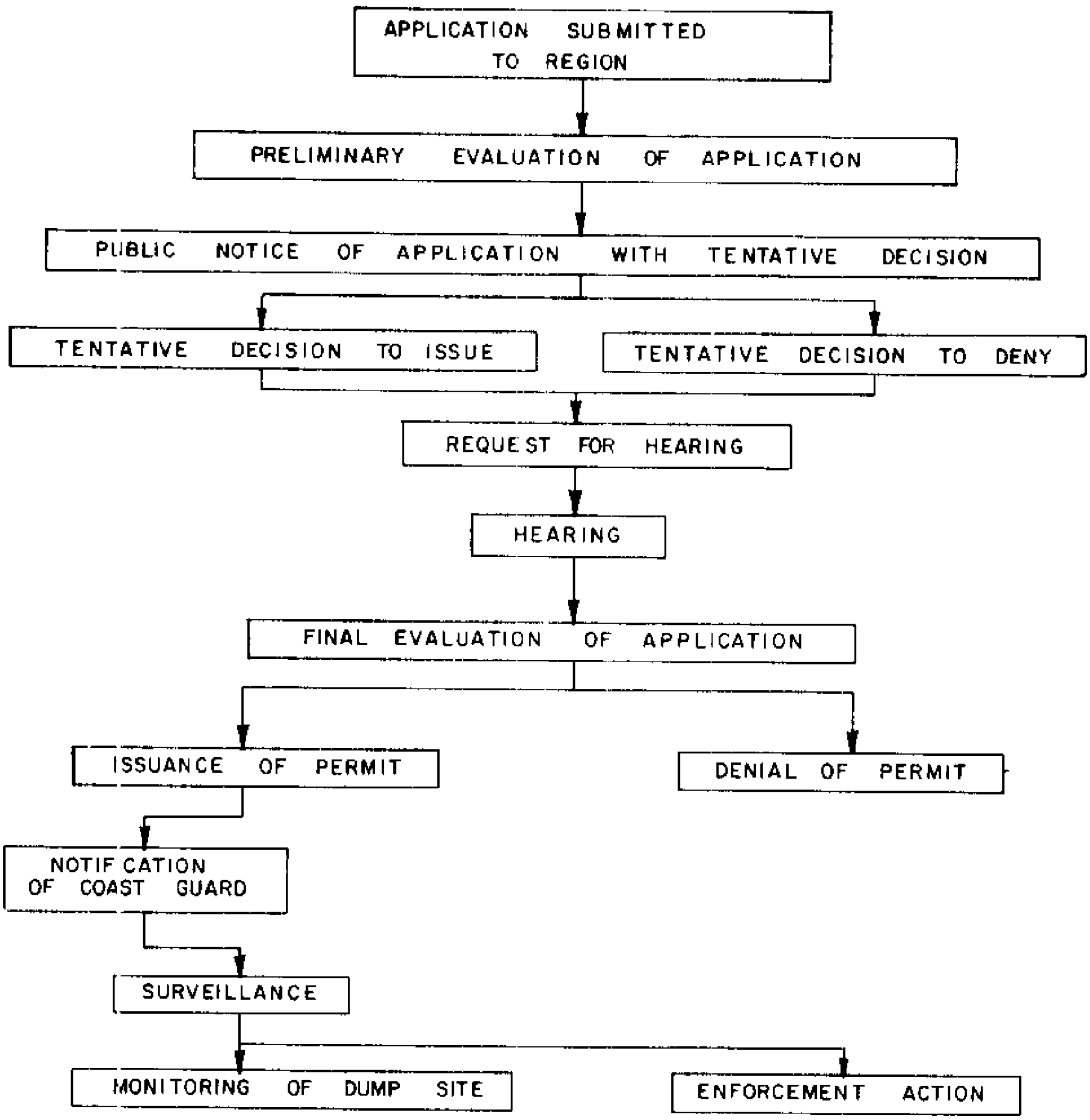

FIGURE 2.4. PERMIT PROCEDURES

(ENVIRONMENTAL PROTECTION AGENCY, 1975) is issued for no more than a year, but it can be renewed if certain conditions are met. Before the permit is granted, an environmental assessment of potential impact has to be presented, and the permittee must show that he is researching alternate disposal methods. An interim permit is granted for a maximum of one year and cannot be renewed, but a new permit can be issued when the present one expires. A research permit is issued for the disposal of wastes to study their effects on the environment. The scientific merit of the research has to be shown to outweigh the potential destruction to the marine ecosystem. A research permit can be issued for up to eighteen months and may be renewed after review.

Permits for the disposal of dredged material are granted by the U. S. Army Corps of Engineers. The proposed permits also have to be reviewed and agreed upon by the Environmental Protection Agency. The Corps of Engineers is to require permittees to use sites designated by the Environmental Protection Agency whenever feasible. The Corps of Engineers may grant use of other sites with a waiver from the Environmental Protection Agency. The waiver has to be granted within thirty days, unless the Agency determines the disposal will have an adverse impact upon the environment.

Disposal Sites

Section 102(c) of Public Law 92-532 authorizes the Environmental Protection Agency administrator to designate recommended sites for disposal, considering the criteria as set forth in the law. When the interim regulations were published, they contained a list of interim dumping sites (Table 2.13). These sites were selected from existing information on ocean disposal. The selections were based on historical usage, rather than environmental criteria. The interim sites were to be used only until the Environmental Protection Agency designates sites that comply with the conditions of the National Environmental Policy Act. The Agency has to prepare Environmental Impact Statements for all disposal sites in use or proposed for use. The preparation of an Environmental Impact Statement requires the collection of data at the site itself and in nearby areas to form the basis for environmental assessment and to predict the impact of waste disposal on the site area (Environmental Protection Agency, 1975).

In selecting a disposal site, the Environmental Protection Agency has to consider a variety of physical, chemical, biological, and atmospheric factors. The oceanography of each area is different; therefore, an assessment has to be made of every proposed site with respect to the material type and method of disposal. The Agency has to be able to predict the impact of the waste material, which includes its dispersion and ultimate effect on marine life. Each area has a capacity to receive and assimilate wastes, and the Environmental Protection Agency has to see that this capacity is not exceeded.

Criteria established by the Agency on May 16, 1973, designated 19 sites whose primary uses were for municipal and industrial waste disposal. As of June, 1975, only 11 of these sites were in active use (National Academy of Sciences, 1976). This phasing out of less

TABLE 2.13. Approved Interim Dumping Sites (Environmental Report, 1975)

EPA REGION I

Location	Size (square miles)	Depth (feet)	Primary Use
Latitude and Longitude			
44°14'N, 68°53'W------------------	2.0	120	Dredged materials
43°33', 69°55'------------------	2.0	100	Do.
42°32', 70°40'------------------	2.0	180	Do.
42°22', 70°40'------------------	2.0	174	Do.
41°24', 71°18'------------------	2.0	108	Do.
41°11', 71°32'------------------	2.0	126	Do.
41°09', 72°53'------------------	2.0	60	Do.
42°26', 70°35'------------------	2.0	312	Toxic waste

EPA REGION II

Location	Size (square miles)	Depth (feet)	Primary Use
Latitude and Longitude			
40°24', 73°51 ------------------	2.0	88	Mud
40°23', 73°49 ------------------	2.0	103	Cellar dirt
40°25', 73°45 ------------------	2.0	90	Sludge
40°20', 73°40 ------------------	2.0	80	Waste acid
40°13', 73°46 ------------------	2.0	200	Wreck dumping
Manasquan River, 20° true, 600 yd from north jetty, light near 40°6', 74°2 .	2.0	20	Sand (hopper dredge)
Absecon Inlet, 140° true, 0.8 to 1.1 miles from south jetty light near 30°21', 74°23'.	2.0	20	Do.
Cold Spring Inlet, 240° true, 1.2 to 1.5 miles from west jetty light, 38°55', 74° 54'.	2.0	20	Do.
106 nmi, 145° true, from Ambrose Light, 38°45', 73°15'.	624	6,000	Toxic chemical waste
19°10' to 19°20'----------------- 66°35' to 66°50'-----------------	--------	6,000	Chemical waste

TABLE 2.13. (Continued)

Location	Size (square miles)	Depth (Feet)	Primary Use
Latitude and Longitude			
Approximately 123 nmi southeast of Ambrose Light, south of 39°0', north of 38°30', west of 72°0', east of 72°30'.	---	6,000	Do.
18°11', 67°12'--------------------	2.0		Dredged materials
18°30', 66°30'--------------------			Do.
17°50', 65°32'--------------------		6,000	Conventional munitions

EPA REGION III

Location	Size (square miles)	Depth (Feet)	Primary Use
Latitude and Longitude			
38°45', 74°47'--------------------	2.0	40	Sewage sludge
38°30' to 38°35'------------------ 74°15' to 74°25'------------------	2.0	120	Neutralized acid wastes
38°20' to 38°25'------------------ 74°10' to 74°20'------------------	2.0	150	Industrial salt waste
38°0' to 38°20'------------------- 73°0' to 74°20'-------------------	2.0	6,000	Arsenic solutions
2½ miles east of Dam Neck, Va. near 36°46', 75°55'-------------	3.0	38	Sand
16 miles northeast of Cape Henry, Va. near 37°05', 75°42'	4.0	63	Silt and sand
37°50', 74°15'--------------------	(1)	6,600	Conventional munitions
33°15' to 33°30'------------------	2.0	Unknown	Dredged material

[1]3-mile radius

TABLE 2.13. (Continued)

EPA REGION IV

Location	Size (square miles)	Depth (Feet)	Primary Use
Latitude and Longitude			
Wilmington Harbor, 38°48', 78°02'	3.5	45	Sand and silt (hopper dredge)
Morehead City, 34°39', 76°42'	11.6	50	Do
Georgetown Harbor, 33°11', 79°08'	1.0	28	Mostly sand and shell
Port Royal Harbor, 32°09', 80°36'	1.4	20	Do.
Port Royal Harbor, 32°05', 80°36'	1.0	21	Do.
Brunswick Bay, 31°02', 81°17'	2.0	29-36	Sand with some shell and silt
Savannah Bar, 31°57', 80°46'	2.0	20-36	Do.
Canaveral Harbor, 28°23', 80°34'	1.6	31	Sand and silt
Fernandina Harbor, 30°42', 81°22'	0.1	37	Sand, shell and mud
Fernandina Harbor, 30°42', 81°24'	0.1	33	Do.
Fort Pierce Harbor, 27°27', 80°15'	0.3	39	Do.
Jacksonville Harbor, 30°21', 81°18'	0.3	31	Sand and shell
Miami Harbor, 25°45', 80°05'	0.13	41-68	Do.
Palm Beach Harbor, 26°46', 80°01'	5.2	26-57	Do.
Port Everglades Harbor, 26°06', 80°06'	0.1	24	Do.
St. Augustine Harbor, 29°54', 81°15'	0.31	36	Fine sand
St. Lucie Inlet, 27°10', 80°09'	0.1	11	Sand and shell
Charlotte Harbor, 26°39', 82°19'	0.7	29	Silty sand and shell
Tampa Harbor, 27°36', 82°45'	0.5	28	Poorly graded sand and shell
Tampa Harbor, 27°33', 82°51'	0.9	32	Do.
Tampa Harbor, 27°38', 82°51'	0.9	24	Do
South of Mobile, Ala., 38°10', 88°06'	0.8	44-48	Dredged materials (hopper dredge)

TABLE 2.13. (Continued)

Location	Size (square miles)	Depth (Feet)	Primary Use
Latitude and Longitude			
Southeast of Gulfport, Miss., 30°10', 88°57'------------------	0.5	23-32	Do.
Southeast of Gulfport, Miss., 30°10', 89°00'------------------	0.4	23-32	Do.
South of Pensacola, Fla., 30°17', 87°19'------------------	0.1	36-42	Do.
South of Pascagoula, Miss., 30°12', 88°33'------------------	0.2	30-40	Do.
South of Panama City, Fla., 30°07', 85°46'------------------	0.5	40	Do.
Port St. Joe, Fla., 29°50', 85°29'--------------------------	0.1	Unknown	Do.
Port St. Joe, Fla., 29°53', 85°31'--------------------------	0.15	Unknown	Do.
South of Carrabelle, Fla., 29°41', 84°37'------------------	1.0	36-42	Do.
South of Carrabelle, Fla., 29°40', 84°39'------------------	1.0	36-42	Do.
31°40', 47°56'--------------------	(1)	7,600	Conventional munitions

[1] 3-mile radius

EPA REGION VI

Location	Size (square miles)	Depth (Feet)	Primary Use
Latitude and Longitude			
Calcasieu Pass, Area A, 29°45', 93°21'------------------	1.0 -----	6+	Dredged materials
Calcasieu Pass, Area B, 29°45', 93°20'------------------	1.0 -----	6+	Do.
Calcasieu Pass, Area C, 29°42', 93°21'------------------	5.0 -----	18+	Do.
Calcasieu Pass, Area D, 29°35', 93°17'------------------	5.0 -----	18+	Do.
Southwest Pass, 28°52', 89°31'----	2.0 -----	45+	Do.

TABLE 2.13. (Continued)

Location	Size (square miles)	Depth (Feet)	Primary Use
Latitude and Longitude			
Waste disposal area, 27°12'-27°28'N, 94°23'-94°44'W	16 miles by 16 miles	2,400	Chemical wastes
Waste disposal area, 28°0', 28°20', 89°15', 89°35'	20 miles by 20 miles	2,400+	Do.
Off Sabine Pass, Tex., Area A, 29°37', 93°50	Approx.5	24	Dredged materials
Off Sabine Pass, Tex., Area B, 29°37', 93°48	Approx.3	30	Do.
Off Sabine Pass, Tex., Area C, 29°40', 93°51	Approx.4	6	Do.
Off Galveston, Tex., Area A, 29°19', 94°40'	Approx.2.5	36	Do.
Off Galveston, Tex., Area B, 29°20', 94°39'	Approx.2.5	30	Do.
Off Galveston, Tex., Area C, 29°17', 94°40'	Approx.7	36	Do.
Off Galveston, Tex., Area D, 29°22', 94°43'	Approx.8	12	Do.
26 degrees, 50 minutes North latitude 27 degrees, 10 minutes North latitude 86 degrees, 50 minutes West longitude 87 degrees, 10 minutes West longitude			
26°20' North latitude 27°00' North latitude 93°20' West longitude 94°00' West longitude			

TABLE 2.13. (Continued)

EPA REGION IX

Location	Size (square miles)	Depth (Feet)	Primary Use
Latitude and Longitude			
21°14', 157°54'	1.0	1,620	Dredged materials
21°55', 159°17'	1.0	2,760	Do.
21°50', 159°35'	1.0	5,100	Do.
33°41', 118°10'	4	90	Do.
34°07', 119°10'	2.0	60	Do.
37°35', 122°50'	2.0	254	Cannery wastes
36°49', 121°50'	2.0	60	Dredged materials
37°46', 122°38'	1.0	36	Do.
30°36', 124°16'	1,500 ft. diameter	70	Do
37°46', 122°33' (Seal Rock)	1,950 yd. long bearing 45° true, 1,300 yd. wide bearing 135° true.	65	Construction material
33°17', 118°10'	2.0		Dry garbage and trash
32°33', 119°06'	2.0		Do.
32°35', 117°17'	1,000 yd radius		Dredged materials
33°37', 118°40'	3-mile radius		Toxics and chemicals
40°46', 124°16'	500 yd	70	Dredged materials
Crescent City, 210° true from Round Rock (41°43', 124°12')	1,000 dia.	90	Rocks
Noyo Harbor, 39°25', 123°50'	500 ft. diameter	100	Sediment erosion material
San Francisco Bar, western end of shipping channel, 2,500 ft. south of channel (37°45', 122°36').	5,000 yds. long 1,000 yds. wide		Dredged material
Moss landing west of ocean pier (36°49', 121°50')	2.0	360	Do.
33°00', 118°55'	3 mile radius	3,000	Conventional munitions
34°40', 122°00'	do	12,000	Do.
37°40', 123°25'	do	6,600	Do.
21°26', 158°38'	do	7,200	Do.
30°20', 131°25'	do	5,000	Do.

TABLE 2.13. (Continued)

Location	Size (square miles)	Depth (Feet)	Primary Use
Latitude and Longitude			
14°32', 120°10'	2 mile radius	3,000	Do.
13°15', 144°15'	3 mile radius	6,000	Do.

EPA REGION X

Location	Size (square miles)	Depth (Feet)	Primary Use
Latitude and Longitude			
46°14', 124°10'	0.3	130	Sand
46°12', 124°09'	0.1	125	Do.
42°02', 124°16'	5 acres	65	Gravel and sand
42°24', 124°27'	0.2	25	Do.
43°07', 124°26'	0.2	50	Sand
43°21', 124°22'	0.2	60	Do.
43°40', 124°14'	2.0	60	Do.
44°01', 124°09'	0.2	70	Do.
46°42', 124°10'	2.0	90	Dredged materials
46°56', 124°07'	2.0	30-35	Do.
61°15', 149°54'	2.0	(1)	Do.
64°30', 165°27'	2.0	(1)	Do.
48°16', 126°58'	3 mile radius	8,300	Conventional munitions
45°35', 123°59'	2.0	(1)	Dredged materials
44°48', 124°04'	2.0	(1)	Do.
44°36', 124°06'	2.0	(1)	Do.

[1]Not specified

EPA HEADQUARTERS

33°55', 08°15'	3 mile radius	6,600	Conventional munitions and dredged materials

suitable sites shows the control the Environmental Protection Agency has started to exercise.

The following discussion will cover three geographic areas: New York Bight, Chesapeake Bight, and the Gulf Coast. Disposal of industrial and municipal wastes from vessels occurs in these areas. These sites were selected to be discussed as typical examples of disposal areas due to the available information on the sites.

The New York Bight. This disposal site is a shallow area shoreward off the limits of the continental shelf, along an indentation of the Atlantic Coast extending about 200 miles from Cape May, New Jersey, to the eastern end of Long Island (Interstate Electronics Corporation, 1973). The disposal areas nearest shore vary from about 6 to 14 miles east of the New Jersey shore. The chemical disposal site is located about 120 miles offshore on the edge of the continental shelf. The following description and illustration (Figure 2.5) of the Bight was obtained from a technical report by Pararas-Carayannis (1973).

The mud disposal site is located at latitude 40°23'48" north and longitude 73°51'21" west at a point not less than seven nautical miles bearing 120° true from Sandy Hook Light. Substances disposed of in this area consist of material dredged from vessel berths, anchorage grounds, and channels. The cellar dirt site is located at latitude 40°22'53" north and longitude 73°48'40" west at a point not less than nine nautical miles bearing 118°30' true from Sandy Hook Light. Wastes disposed of at this area consisted mainly of earth and rock from cellar excavations and non-floatable debris from

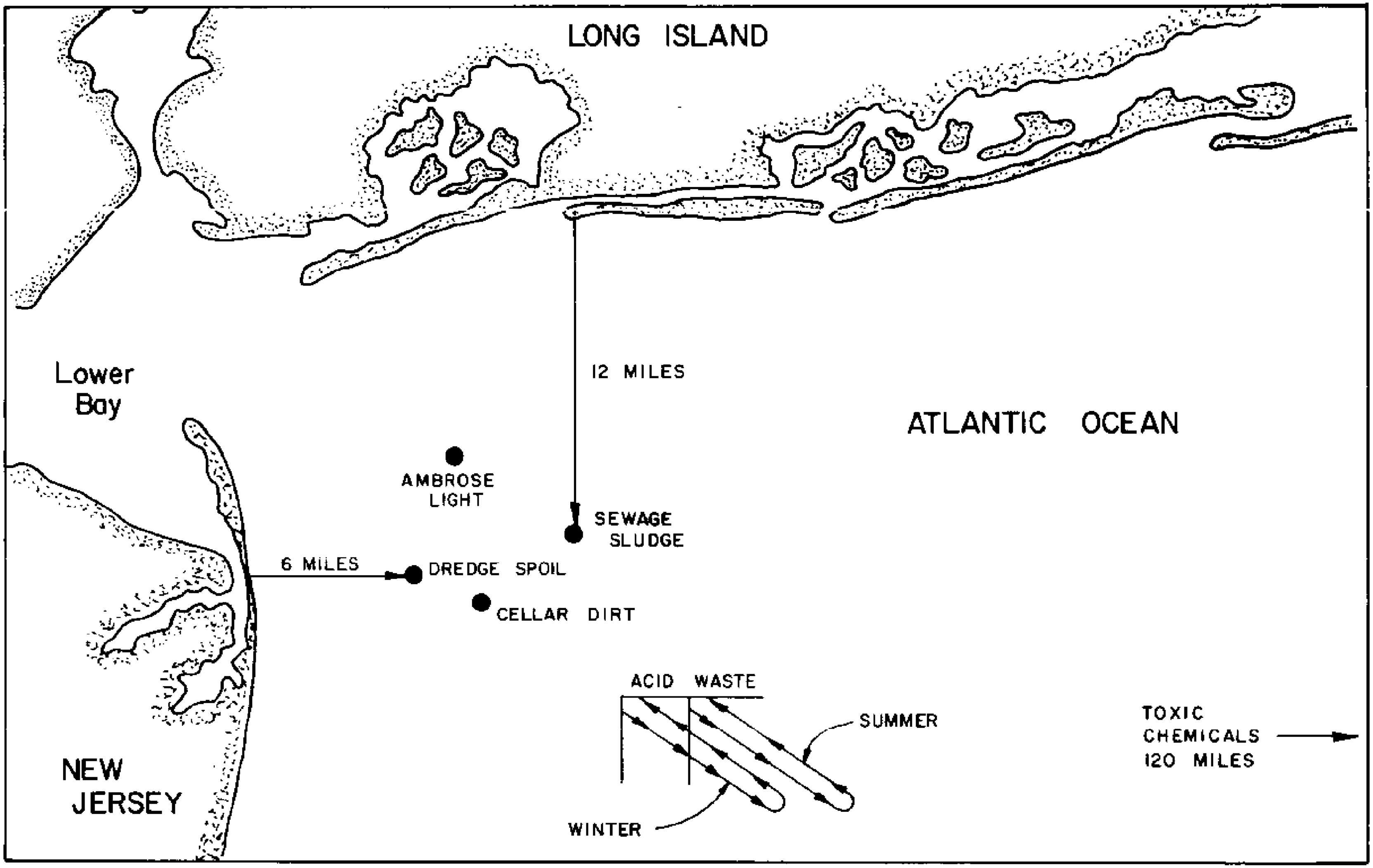

FIGURE 2.5. THE NEW YORK BIGHT DUMPING GROUNDS
(PARARAS - CARAYANNIS, 1973)

building demolition and highway construction work. Found offshore of a point not less than 11 nautical miles, 103° true from Sandy Hook Light, at latitude 40°25'04" north and longitude 73°44'53" west is the sewer sludge disposal site. The wastes are either in a raw, treated or digested state and come from the cities in New York and New Jersey. Located at a point not less than 13 nautical miles 66° true from Sea Girt Light at latitude 40°13'32" north and longitude 73°46'02" west disposal of obsolete vessels, wrecks, and other submerged obstructions to navigation occurs. The waste acid site, southeast of a point about 16.3 nautical miles 120° true from Sandy Hook Light, is located south of latitude 40°20' north and east of longitude 73°40' west during the summer; but during winter the area is south of latitude 30°20' north and east of longitude 73°43' west. The waste chemical disposal area is 120 nautical miles southeast of New York within an area bounded on the north by latitude 39° north, on the south by latitude 30°38' north, on the east by longitude 72° west, and on the west by longitude 72°30' west. The depths at this site at the edge of the continental shelf are greater than 7000 feet.

The Gulf Coast. Two disposal sites (Figure 2.6) in the Gulf of Mexico off the coasts of Texas and Louisiana are used for the chemical wastes of industries. The site south of Galveston has the following boundaries: latitudes 27°28' north and 27°44' north and longitudes 94°28' and 94°44' west (Interstate Electronics Corporation, 1973). The area of 226.87 square nautical miles has an approximate volume of 89.61 cubic nautical miles or 2.013×10^{13} cubic feet. The

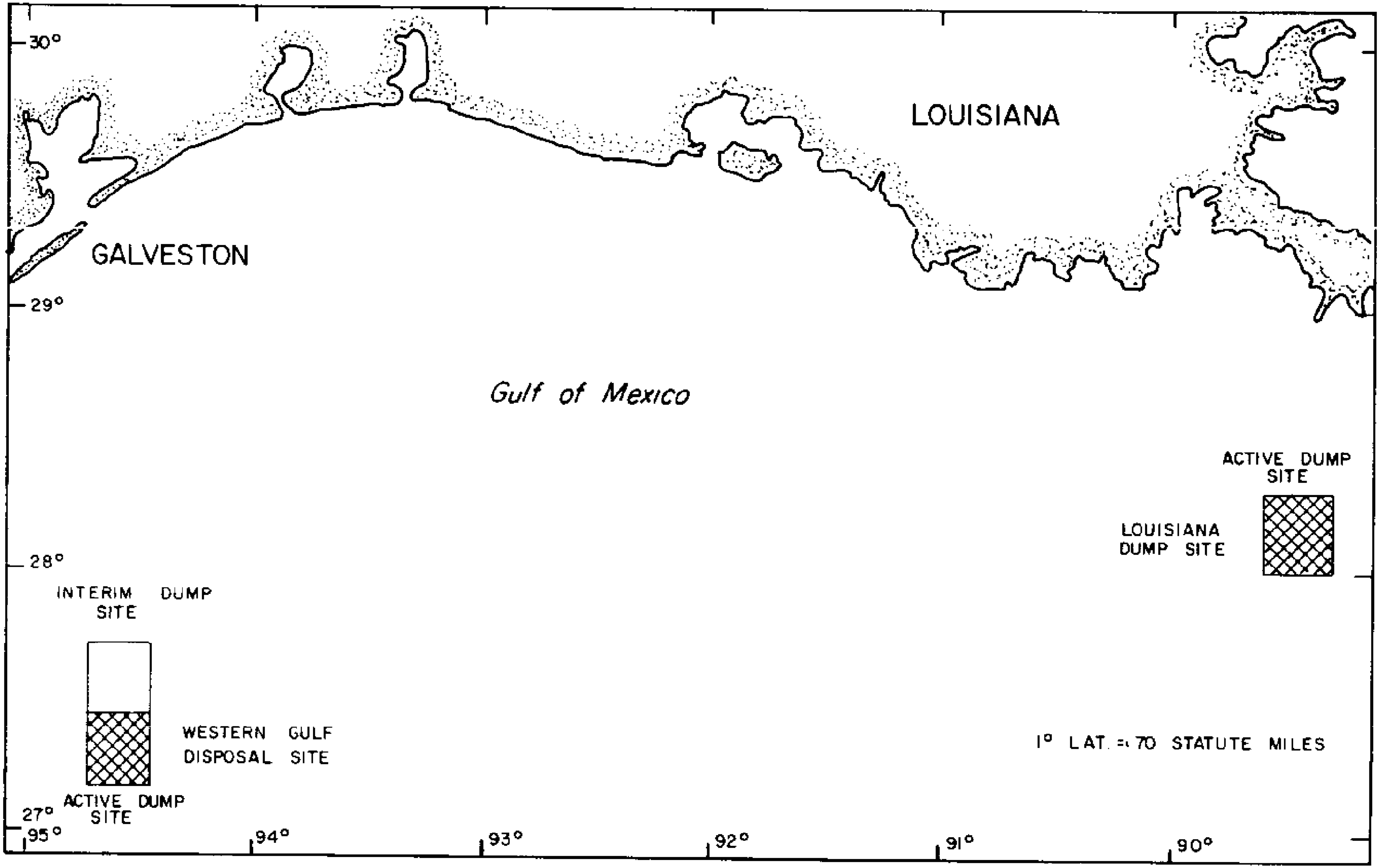

FIGURE 2.6 INTERIM AND ACTIVE DUMP SITES IN THE GULF OF MEXICO
(ENVIRONMENTAL PROTECTION AGENCY FILES)

depth ranges from 780 to 3240 feet with an average of 2400 feet. As of 1976, this site was only used by Shell Chemical Company for the disposal of its bio-sludge.

Located south of New Orleans at latitudes 28°00' north and 28°20' north and longitudes 89°15' west and 89°35' west is the second disposal area. The site covers an area of 352.63 square nautical miles with a depth range of 2400-4200 feet and contains an approximate volume of 202.75 cubic nautical miles or 4.562×10^{13} cubic feet (Interstate Electronics Corporation, 1973). The site which is presently not in use was last utilized by Ethyl Corporation to dispose of a sodium-calcium sludge.

The Chesapeake Bight. This bight area which is off the coasts of Maryland and Delaware consists of two major disposal sites (Figure 2.7). One site which is 40 miles east of Ocean City is used by the City of Philadelphia to dispose of approximately 640,000 tons of sewage sludge per year (U.S. Department of Commerce, 1975). Another site is located 38 miles east-southeast of Cape Henlopen, Delaware. It has been used by the DuPont Company since 1968 for ferrous sulfate and sulfuric acid wastes. About 20 million gallons per month are dumped from barges at this site.

Limiting Permissible Concentrations

The Environmental Protection Agency (1973) published the definition of the limited permissible concentration of waste materials to be disposed of in the ocean in "Ocean Dumping, Final Regulations."

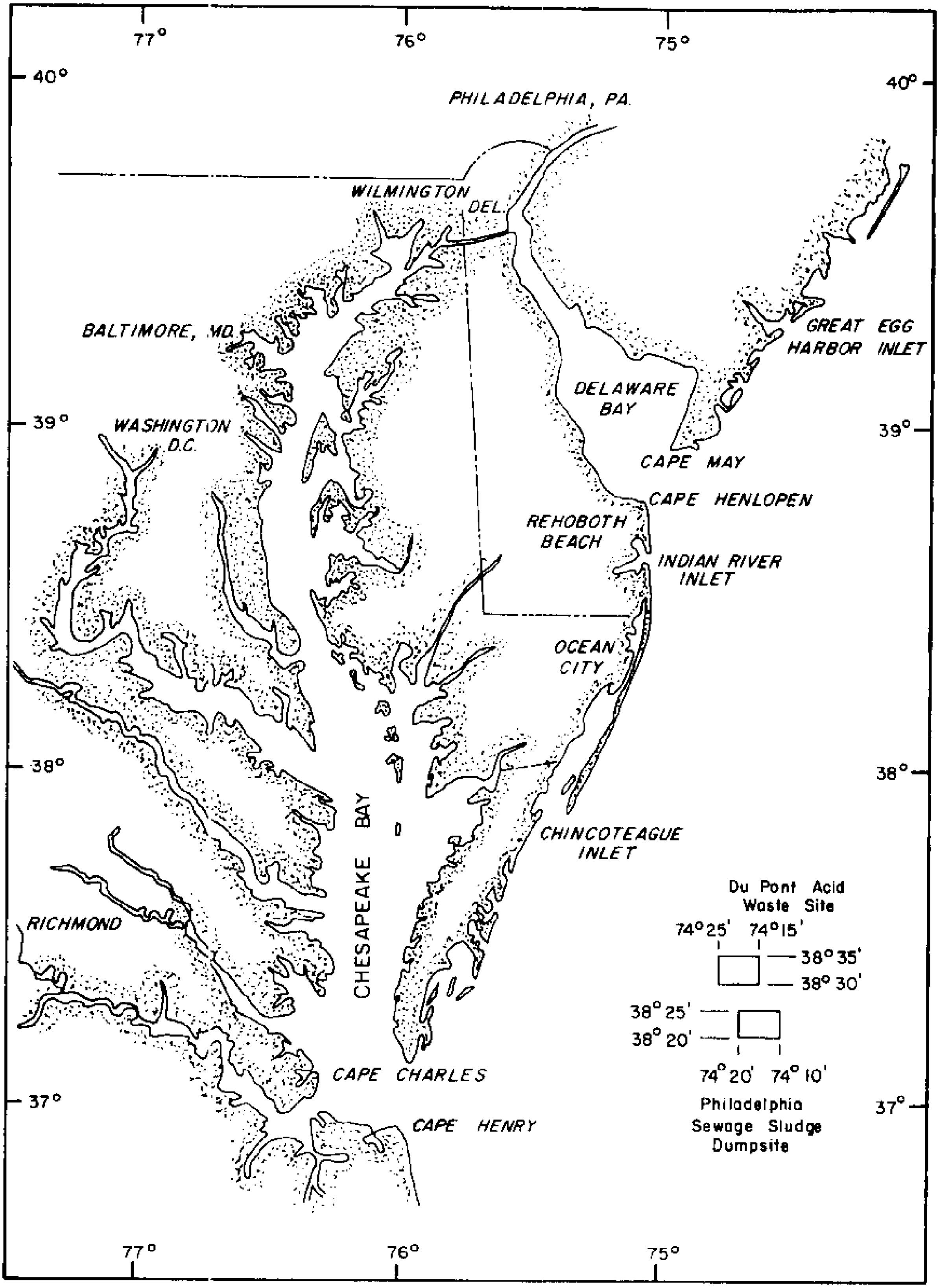

FIGURE 2.7. CHESAPEAKE BIGHT DUMPSITES
(U.S. DEPARTMENT OF COMMERCE, 1975)

It can be defined as:

(1) That concentration of a waste material or chemical constituent in the receiving water which, after reasonable allowance for initial mixing in the mixing zone, will not exceed 0.01 of a concentration shown to be toxic to appropriate sensitive marine organisms in a bioassay carried out in accordance with approved EPA procedures; or

(2) 0.01 of a concentration of a waste material or chemical constituent otherwise shown to be detrimental to the marine environment.

There are some problems connected with this definition. No time period is specified to determine the acute toxicity level. The Agency's overall safety factor applies only to acute toxicities. Chronic effects can be very detrimental and even lead to death of the organism, but chronic toxicity is not even mentioned in the permissible concentration. The allowable level can be calculated by dividing the acute toxicity by the factor of 100. This safety factor is suitable for acute/chronic ratios of less than 100, but when the ratio is greater than 100, a larger factor is needed. Safety factors should be determined for individual categories of wastes. Municipal and industrial wastes have different toxicity levels, and therefore, each category should have an applicable safety factor. In order to conclusively determine more appropriate safety levels, the chronic effects will have to be investigated more thoroughly.

Alternatives to Ocean Disposal

Section 203 of the Marine Protection, Research and Sanctuaries

Act of 1972 stated that ocean dumping be minimized or ended completely within five years of the effective date of this Act. As a result of the legislation, all permits required that the permittees develop alternate disposal methods for their particular wastes. If the alternatives were found to be technically and environmentally feasible, the permittees were requested to replace ocean disposal with the alternate methods. Some of the significant alternatives examined were deep-well injection, incineration, storage, various forms of land disposal, recycling and advanced treatment.

Deep-well injection. The most influencing factor in choosing an alternative is the type of waste material. Some alternate methods are not suitable for certain type wastes. For example, deep-well injection is not feasible for sewage sludge disposal. The solids content of sludge would prevent injection into subsurface formations.

Some industries have turned to this method rather than ocean dumping. The GAF Corporation in Texas City, Texas employed deep-well injection wher their ocean disposal permit expired in December 1974. The costs of injection have been found to be slightly cheaper than ocean disposal, but there are problems associated with this method.

A suitable zone has to be found for injecting the waste because the geological formation and the waste have to be compatible. In addition, the formation must not allow migration of the waste into other formations. Ideally the waste should be injected into a porous medium overlaid by an impervious rock or stone formation to prevent contamination of oil and gas reservoirs, or potable aquifers. The casing and cementing have to be done properly to protect against leaks and fluid migrations into other zones.

Other common problems associated with deep-well injection are corrosion of the well tubing and plugging up of the formation with solids not removed from the waste. Despite these potential shortcomings, many industries actively utilize this method. However, the future of this alternative is still uncertain. The recently passed Safe Drinking Water Act (P.L. 93-523) contains a provision pertaining to deep-well disposal of wastes. The stringent requirement of this provision may force some industries to re-evaluate this alternative.

Incineration. Until recently, incineration of wastes was a land-based operation in the United States. The Shell Chemical Company introduced a new alternative when they incinerated their organochlorine wastes aboard a specially designed ship in the Gulf of Mexico. The results of this operation proved ocean incineration to be a viable alternative. Many industries and municipalities currently dispose of their wastes using incinerators on land, but this has been questioned because of possible air pollution fallout. Air pollutants could pose potential dangers to people living near the incinerators. As long as particulate matter is prevented from entering the atmosphere, incineration will remain a feasible alternative. Increasing fuel costs could force incineration into economic jeopardy because incineration requires large quantities of energy to operate.

Land-based storage. Storing wastes in containers at land sites is one way of avoiding ocean disposal. Liquid radioactive wastes are presently stored in tanks at land-based sites. This disposal method has been proposed for the disposal of industrial wastes which can be stored in tanks or drums. Large spaces of land are required for the placement of the storage containers. Land-based storage has to be monitored frequently to insure that there are no leaks or spills. A few industries store wastes until other forms of disposal become available or feasible. Storage prevents wastes from entering the environment, but problems could arise if there are not available areas for the storage containers.

Land disposal. These methods consist of placing the wastes on land or intermingling them with the land. These alternatives are used because soil is a natural biological treatment (Dean, 1971). Filtration through fine soil removes all particulate matter. Most cations and some anions are strongly adsorbed by soil minerals. Organic materials are decomposed by soil bacteria. The maximum loading rate depends critically on the way the land is used. If used solely for the destruction of organic wastes, the soil can perform the function at much greater loading rates than can be tolerated if crops are grown. Waste application is impractical during severe winter weather because the biological processes slow down. The wastes can be placed in storage lagoons until weather conditions are appropriate.

Placing wastes in a sanitary landfill is an acceptable method for disposing of such materials as sludges, garbage and refuse. Landfills are best for disposing of dry matter. Organic wastewaters can be spray-irrigated over croplands or sprayed over permanent pastures and forest lands. Organic materials can also be converted to fertilizers and soil conditioners and then spread on land. Several cities in the United States use this procedure to get rid of their municipal wastes.

These methods require large land areas and the procurement of reasonably priced land is difficult, especially in metropolitan areas, which also do not have the available space. The sites should be remote from sources of water supply and recreation, and suitability of the soil and possible future use of the property should be considered in selection of the sites.

There are numerous problems associated with land disposal. Leachates from the wastes can contaminate surface and groundwaters. Nitrates can pollute the drinking water supply and present a health risk to man. Contaminants from runoff can enter water sources. Trace metals in wastes are also possible pollutants. Viruses, bacteria, spores and intestinal parasites of certain wastes can have detrimental effects on man if allowed to enter the water system.

Recycling. The complete reclamation and reuse of waste materials is the only method which prevents the materials from polluting the environment. Recycling is practiced by some groups, but on a small scale. For example, paper, aluminum and ferrous metals can be extracted from solid wastes. Problem of recycling include separation of the materials and a poor secondary market. Recycling on a plant scale and at a reasonable cost is not yet feasible. All materials cannot be recycled, therefore, this method is unacceptable for many types of wastes.

Advanced treatment. Methods are available to help detoxify wastes and make them more disposable. Carbon adsorption is a method used in conjunction with other treatment processes. This treatment removes harmful organic constituents by adsorption on activated carbon beds. Spent carbon beds are reactivated by incineration which burns off the organics.

Treatment methods to render wastes less harmful are very numerous. Bioxidation practices include trickling filters, activated sludge or lagooning. Industrial wastes can be treated by techniques such as ozonation, solvent extraction, neutralization, and air-stripping. Acid wastes can be neutralized by upflow through limestone beds. Organics can be stripped from wastes by passing air through the material. These treatment practices do not completely solve the disposal problem; the remaining materials from the treatments still have to be placed somewhere.

Trends

Ocean disposal of wastes has been practiced since the early 1900's, but earlier releases were neither well documented nor regulated; therefore, tonnage of earliest disposal has not been quantitatively tabulated. Historical trends from 1949 to 1968 showed a fourfold increase in tonnage of wastes, excluding dredged material, explosives, and radioactive wastes due to lack of data, from vessels (Council on Environmental Quality, 1970). Industrial wastes disposed of in the ocean in 1959 totalled approximately

2.2 million tons, but by 1968 the quantity had increased to over 4.7 million tons, a 114 percent increase in nine years. From 1959 to 1968, ocean disposal of sewage sludge increased from 2.8 million tons to 4.5 million tons, an increase of 61 percent. Figure 2.8 illustrates these sharp rises on tonnage.

In 1973, industrial wastes increased to 5.4 million tons and sewage sludge to 5.4 million tons. The year 1974 found only slight increases: industrial waste total of 5.7 million tons and sewage sludge total of 5.7 million tons (U. S. Environmental Protection Agency, 1975). Solid waste disposal at sea is almost totally non-existent with only 240 tons discharged in 1974 (U. S. Environmental Protection Agency, 1975). Explosives and radioactive wastes are no longer dumped off the coasts of the United States. The total dredged material dumped in the ocean is constantly increasing as evidenced by the increase from 44.2 million cubic yards in 1973 to 98.7 million cubic yards in 1974 (Cox, 1975; U. S. Environmental Protection Agency, 1975).

Although the total quantities of wastes disposed of in the ocean increased up to the year 1974, decreases in the number of dumpers has occurred since the Environmental Protection Agency began implementation of a strictly regulated permit program. In order to receive a permit, a potential dumper has to show a need for ocean disposal and present alternate methods. Since enactment of the permitting system, many entities have had their permits denied or they have

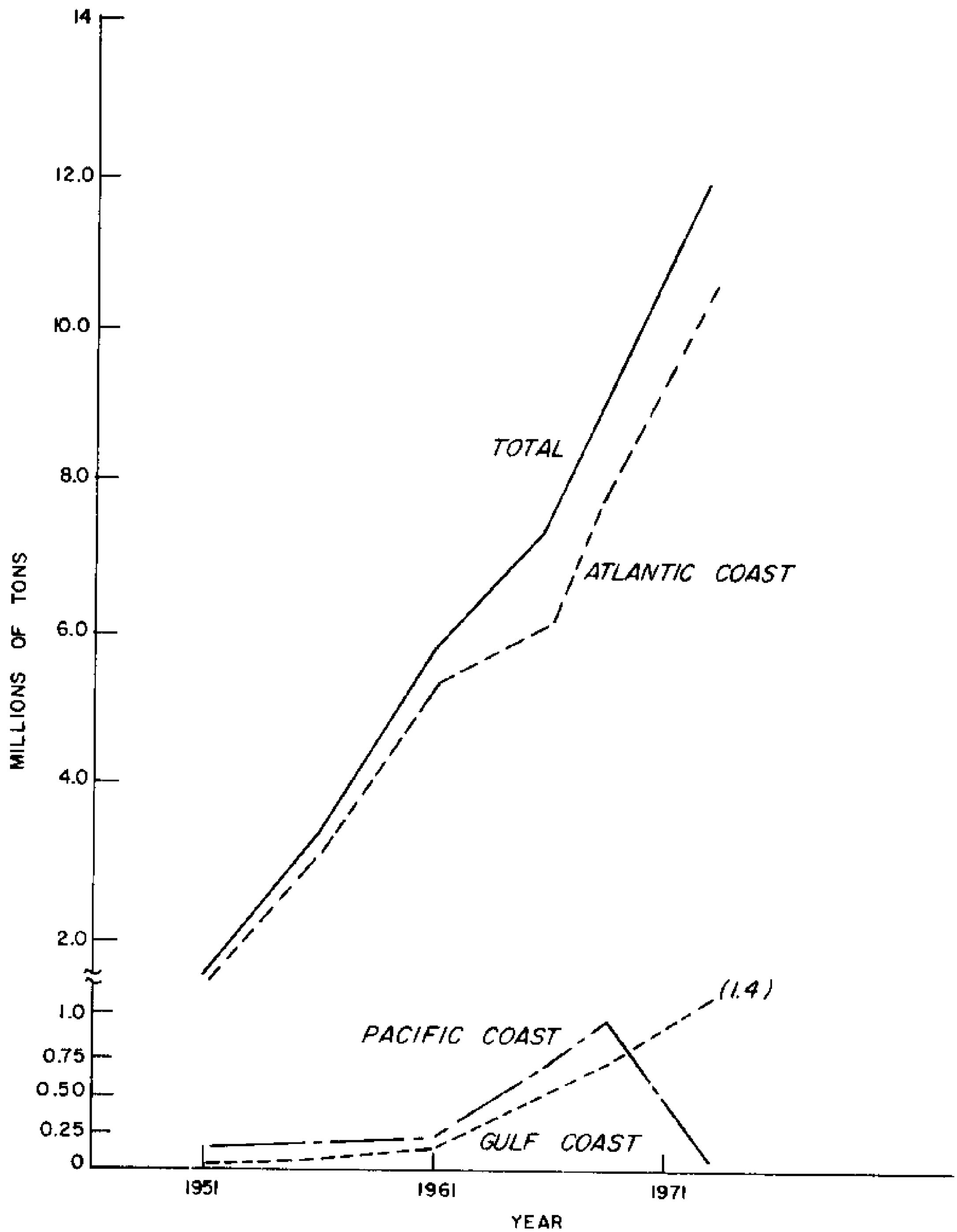

FIGURE 2.8. OCEAN DISPOSAL EXCLUSIVE OF DREDGE SPOIL AND PIPE DISCHARGE

(NATIONAL ACADEMY OF SCIENCES, 1976)

since developed suitable alternatives. For example, on the Atlantic coast 47 former dumpers ceased dumping since enactment of the Marine Protection, Research and Sanctuaries Act of 1972. Nine companies either withdrew their applications or were denied permits. Another 14 groups were scheduled to cease ocean disposal in June, 1975 and eight more in June, 1976. By the end of 1974, only four of the seven original permittees continued dumping in the Gulf of Mexico (U.S. Environmental Protection Agency, 1975). As of 1976, only one company received a permit to continue ocean disposal in the Gulf.

Although the federal legislation has been successful in reducing the number of permittees, the future of ocean disposal is still questionable. The Federal Water Pollution Control Act Amendments of 1972 (P.L. 92-500) proclaim the following goal: zero discharge of pollutants into the Nation's waters by 1985. This applies to ocean disposal either by outfall or dumping. Many doubt that this goal will be attained by that date or if it is even practical. Industries and municipalities in metropolitan areas often lack available space for many of the alternatives. The amount of sewage sludge to be disposed of will continually increase because P.L. 92-500 requires that all sewage treatment plants provide secondary treatment by mid-1977. As a result of this further treatment, more sewage sludge will be generated. The total volume of dredged material is also expected to increase because navigation channels will continue to require deepening.

If the legislation remains unchanged, then ocean disposal can be expected to eventually cease. In the future, this might be altered if wastes are proven to cause no harm to the marine environment. The ocean may be the best disposal receptacle for non-polluting wastes.

CHAPTER III

PHILOSOPHICAL ASPECTS OF OCEAN DISPOSAL

Numerous philosophies have been developed concerning ocean disposal of waste materials. These philosophies have originated from the conflicting and diversified opinions people have formulated. Every person sees an aspect of ocean disposal in a different perspective. The discussion of the following philosophies tries to point out a pro and con side to each issue when possible. Each viewpoint is unique in its own way, but it may show a relationship to some of the other philosophies as will be shown in a later chapter.

Significance of the Ocean

One vital aspect of the ocean is its importance to man. The ocean is a reservoir containing 92 percent of all water on earth (Smith, 1972). Its waters also act as a receptacle into which dissolved substances and particulate matter from the land accumulate in, thereby becoming a reservoir of minerals. Because of the thermal properties of water, energy stored in the ocean is released to the atmosphere, therefore aiding to moderate the climate and to sustain the wind systems. One of the essential areas of the earth is the interface of the air and water, the narrow band at the bottom of the atmosphere and the top of the ocean (Dallaire, 1971).

It is here that the oxygen produced by the phytoplankton enters the atmosphere where it contributes an estimated 70 percent of the earth's oxygen supply.

The ocean is also important to man as the source of hundreds of products derived from living and nonliving resources. Food ranks high as one of the major uses of the ocean. The world sea harvest is about 55 million metric tons per year (Holt, 1969). This is one of the major sources of protein for man. The floor of the ocean will be increasingly exploited in the future. Research in the field of medicine has led to the discovery of toxins, drugs and pharmaceuticals from marine organisms.

Man has for many ages looked to the ocean as a means of tranportation and recreation. Traveling across the oceans has aided man in economy and warfare. Popular sports of marine recreation include swimming, fishing, boating, skiing, surfing, and skin diving. One must remember the most popular marine recreation activity - ocean watching (Hood and McRoy, 1971).

The dispute over ocean disposal brings a question to mind: is the land or the ocean more important to man? Dr. Kenneth Emery of Woods Hole Oceanographic Institution contends that man has much more ocean floor to waste than dry land (Andreliunas and Hard, 1972). One must ask if it really matters if some species of marine life fail to survive man's impact in restricted areas of the ocean (Newell, 1972).

According to Dallaire (1971), large areas of the continental shelf are essentially barren, devoid of bottom-dwelling animal life, and the best human use for these areas is as a receptacle for wastes. Newell (1972) repudiates this in that he feels the shallow waters of the continental shelf are important in the cultivation of marine animals for food. This is also the zone which is most vulnerable from toxins derived from the land nearby, and it will most likely be affected by industrial exploitation in the near future.

The Ultimate Sink

A general attitude that has existed among people for many years is the belief that the ocean is the ultimate sink of the world, since virtually all pathways lead to the ocean. The hydrologic cycle (Chow, 1964), which is the continuous cycling of water between the atmosphere, lithosphere and hydrosphere, is the scientific basis for this belief. This perpetual water cycle is composed of the processes of evaporation, precipitation, interception, transpiration, infiltration, percolation, storage, and runoff (Figure 3.1).

Those who accede to this philosophy feel that man should go ahead and directly dispose of waste materials in the ocean, because the wastes will eventually end up in the ocean through other means. This opinion is expressed in an article by Adler (1971):

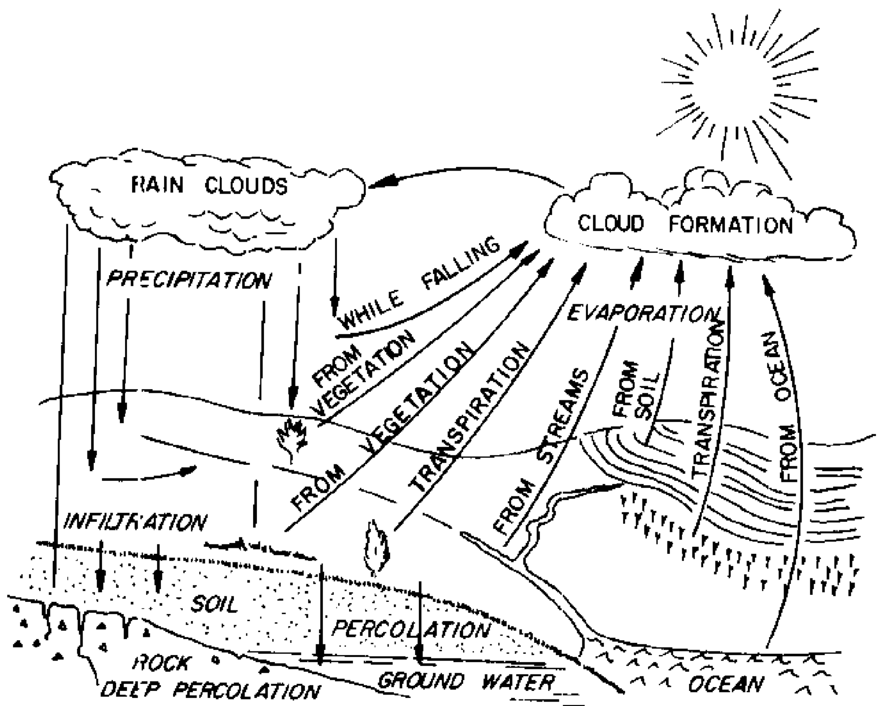

FIGURE 3.1. THE HYDROLOGIC CYCLE – A DESCRIPTIVE REPRESENTATION.

(ACKERMANN, et al., 1955)

> Since all rivers run down to the sea, even those wastes not directly dumped into the oceans may ultimately end up there. Air pollutants precipitate back, or carried back in rainfall, to earth. Most eventually find their way to the sea in the form of runoff.

The ocean collects staggering amounts of atmospheric and fresh water pollutants. Dallaire (1971) agrees that many contaminants reach the ocean indirectly:

> The amount of waste dumped into the ocean is small compared to the total volume of sewage, chemicals, garbage and other wastes flowing into the sea from the world's river.

Since the ocean already receives these many wastes in a roundabout way, why should one expect that the occasional human releases of a little more would have much effect.

Opposition to this belief is based upon the idea that the ocean is already being polluted, so why add to the problem through the practice of ocean disposal. The pathways which lead to the oceans have carried natural contaminants for millenia, but only in the last century have these materials been supplemented by man-made substances.

The method of ocean disposal tends to concentrate the wastes in a smaller area, while materials reaching the ocean through other means tend to become degraded, precipitated or absorbed while in transit. By the time these materials reach the bays or estuaries leading into the ocean, natural mechanisms could have reduced or utilized them. Marine life in the shore areas can assimilate the wastes; while other matter settles to the bottom of the rivers and estuaries before it reaches the ocean. The hydrologic cycle also plays a role in dispersing the materials from the inland waters.

The Infinite Sink

Since the beginning of human history, the oceans of the world have usually been thought to be inexhaustible in all their resources, including the degree to which they favorably receive the wastes of man (Hood, 1971). The key to this concept is man's attitude concerning the size of the ocean. The total oceans which cover 71 percent of the global surface have a volume of 328,750,000 cubic miles (Chow, 1964). With such a vast volume, how could man adversely affect the oceans with his disposal of wastes? According to Moorcraft (1973), "How could he possibly undo the work of 3,000 million years in a few decades?" To man, the ocean is inconceivably extensive, so why should he not dispose of his wastes in this limitless sink.

This concept is challenged by those who believe that the ocean is finite. There are limits to what degree it can receive the wastes of man. Thor Heyerdahl, after one of his expeditions across the Atlantic, commented that "the ocean is not so endless as we are accustomed to think..." (Newman, 1970). On his trip he found almost constant evidence of man-made debris even in mid-ocean. This is just one example of evidence available that challenges the long held concept of the ocean as an infinite sink. Hedgpeth (1970) also agrees that the ocean should not be a pollution sink:

> The ocean is obviously not an infinite sink into which everything may be dumped; certainly not the upper layers, contaminated at the surface by fallout of man's many antiecological activities and at shallow depths by sewer outfalls.

The ocean is not a sink which can have its plug pulled to drain man's wastes out. Instead, the ocean is a system of life and its many processes.

Conservation of Matter

The law of conservation of matter can be applied to the practice of ocean waste disposal. Wastes cannot be destroyed, only transformed. What the oceans do not receive, the land or air environments must. Since man is in close contact with the land and air, why should he further damage the environment in which he lives when he has the whole ocean in which to dispose of his wastes. The following is a remark of Morris Klegerman as stated in Dallaire (1971) concerning alternate methods of disposal:

> Incineration does not destroy sludge, but merely changes its form. Does this solve a problem? Does the air environment have more assimilative capacity than the ocean? Can people tolerate "dead air" more readily

> than twenty square miles of dead sea? Is the assimilative capacity of the atmosphere greater than that of the sea, or less? A large part of air pollutants eventually end up in the ocean anyway, because rain washes them out of the sky.

The statement by Klegerman leads one back to the theory of the ocean as the ultimate sink. Since the wastes eventually end up there, why not dispose of them there in the first place. Also, he questioned the assimilative capacity of the atmosphere compared to the ocean's assimilation. The concept of "out of mind, out of sight" was brought up in that people care more about the air than the ocean due to the close proximity of the atmosphere. This quotation is one example of how closely the different philosophies are related.

The opposition can make the counterpoint that ocean disposal does not solve the dilemma of freeing man of his wastes. As Miller (1970) says, "Ocean disposal merely transfers the waste problem elsewhere." This problem is not solved because the wastes are not destroyed. These materials are only converted to different forms; they are not always rendered harmless.

Assimilation Capacity of the Ocean

Assimilation can take place by two mechanisms: abiotic and biotic. The abiotic factor is mainly associated with the vast volume of the ocean and its water movement and circulation mechanisms. The biotic aspect consists of the biochemical processes of marine life.

These two factors combine to aid the ocean in acting as an absorbing system which utilizes the materials introduced into it.

One of man's concepts of the ocean is the idea that its capacity for assimilation cannot be overwhelmed. The ocean can assimilate many different wastes, due to its immense volume and inexpensive resource for waste assimilation without harm to the ecological balance. The following is an assertion of this belief (Adler, 1971):

> There are twelve billion cubic feet of ocean available for the disposal of the wastes from each individual on earth. Sanitary engineers estimate that normal sewage can be mixed with seawater in the ratio of one part sewage to 200 parts water and still allow biochemical processes in the water to naturally purify the waste to a harmless state.

Formerly pollution resulting from waste disposal in the oceans was of little concern due to the seemingly limitless capacity to absorb and assimilate these wastes; now it has been found that every body of water has a limited capacity to absorb and neutralize inflowing materials (Hood and McRoy, 1971). Evidence of this limited capacity to absorb some man-made artifacts such as pesticides, and radioactivity can be found by examining the tissues of marine organisms.

Perhaps one way to guarantee that the assimilation capacity would not be overcome is to distribute the wastes over large areas. Then the materials would be diluted to a level that could be utilized by the metabolic capacity of ocean biota through incorporation into body materials (Hood, 1971).

Mixing and Dilution

The physical processes of mixing and dilution in the ocean are closely entwined. Dilution of wastes in the ocean often, but not always, follows the natural phenomenon of mixing. Mixing causes the waste products to be dispersed, which in turn leads to dilution of the materials.

There are reasons to believe that these physical processes will aid in making the disposed wastes less harmful. According to Marx (1967),

> The ocean is considered - and quite properly - as a mixing process, which, stirred by powerful currents, is supposed to dilute the noxious and obnoxious.

There are many types of oceanic motions: the familiar surface waves, the slow currents deep within the sea, the oceanic currents such as the Gulf Stream and the Black Current, and the Swift tidal streams of harbor mouths (Capurro, 1970). Every drop of seawater is constantly in motion. On an average, most of the oceans move at approximately 5 cm per second (0.16 feet per second) (Adler, 1971). Coker (1954) also substantiated that there is mixing in the oceans by the following:

> The seas, all together, constitute a great dynamic system with an intricate and worldwide mechanism for mixing everything soluble that comes into it...

When justifying the practice of ocean disposal by mixing mechanisms, one must keep in mind exactly where in the ocean ultimate mixing and dilution take place. The near-shore areas have more predominate and efficient mixing. The effects of waves, tides, and currents are exerted noticeably in the coastal zones where greater depths result in a greater volume of water. But complete dispersion in the water column of the open ocean is not always possible. Lack of mixing actions and density stratifications can prevent complete dispersion and ultimate dilution.

The problem with ocean disposal is that man tends to concentrate the wastes in rather restricted areas. Too much of any material in one area can prevent these physical processes from properly taking place. Often small amounts of substances prove no harm, but large amounts of materials such as sludge and dredged materials can overpower the system. Nutrients in wastes are known to be harmful to ocean life if allowed to concentrate in quantities.

Marx (1967) stated that "the mixing process of the ocean not only has its limits but its own idiosyncrasies." Materials disposed in the ocean may be diluted, but shellfish are one type of marine organisms that filter out and concentrate finely diluted compounds. So even if the waste materials are effectively diluted, they might still pose a danger to the marine organisms that ingest them due to biological magnification.

Ocean Versus Estuary

One influential reason for the disposal of materials in the ocean is the preservation of the nation's estuaries. More than thirty of the United States important commercial species of fish, molluscs, and crustacea spend a part or all of their lives in an estuary (Marx, 1967). For these and other marine species, the estuaries also serve as spawning grounds, nursery grounds, and places to live. These productive areas are very important to the fishery harvests of this nation. Odum (1971) expresses this point of view:

> The dependency of so many important commercial and sport fisheries on estuaries is one of the major economic reasons for preservations of these habitats.

Harvey Ludwig, an environmental engineer, maintains the following (Dallaire, 1971):

> The biological value of a typical estuary is 1,000 times greater per unit area than the ocean deep.

Martin Lang of New York City also asserts his thoughts on the biological significance of the estuary over the ocean in the next statement as quoted in Dallaire (1971):

> The estuarine waters are the classic spawning grounds of marine biota... The total BOD we

> are imposing on a couple of barren square miles of offshore water is less than one-sixth of that discharged in the upper harbor of New York City... It is like talking about a hang nail when there is a broken leg to be treated.

Lang feels that too much attention is being focused on the oceans and practically no thought to the estuaries which are of more importance to marine life.

Why stop ocean disposal when the materials dumped in the estuarine areas will end up in the ultimate sink? Ludwig believes in this philosophy (Dallaire, 1971):

> Banning ocean discharges solves little in that the estuaries and bays are themselves pipelines to the sea. The toxicants... and biostimulants ultimately end up in the ocean anyway.

Some people argue for the disposal of certain wastes in the estuaries and contiguous zones. Certain waste materials may act as nutrient or food sources to some marine biota. Sewage sludge, which contains varying amounts of phosphorus, nitrogen, and organic carbon, is such a waste material with nutrient potential. Some of the non-toxic industrial wastes may also provide sources of food for estuarine life. Solid refuse, such as wrecked automobiles, can be used to create artificial shelters for fish in the estuaries, thereby helping to increase the productivity of the area.

There is also the possibility that the wastes disposed of in the estuaries would have a better chance of degrading or settling. Greater amounts of biological life are available in the estuaries where the materials could be broken down and assimilated by the plants and animals. Also, the suspended solids in these areas tend to absorb toxicants and nutrients, and settle to the bottom of the estuary.

Waste or Nutrient?

The disposal of many organic wastes such as sewage sludge and fertilizer residues into the ocean presents the controversial question of whether the waste acts as a pollutant or as a nutrient. In this discussion domestic sewage sludge is used as an example of a waste rich in nutrients. Sewage sludge disposed of at sea is the residual from municipal sewage treatment plants and is generally three to ten percent solids by weight (Smith and Brown, 1970). The characteristics of sludge vary depending on its origin, the amount of aging that has taken place, and the type of processing to which it has been subjected (Metcalf and Eddy, 1972).

Advocators of disposing of sewage sludge in the sea believe that the sludge enriches the sea with the nutrients it contains. For years dried sludge solids have been used as a soil-fertilizing agent in Milwaukee, Houston, Chicago, and other cities which sell this sludge. An example of the many micro-nutrients in sludge can be found in Milorganite, the bagged, dried sludge sold by Milauwkee, in the following percentages: nitrogen, 6.00 percent; phosphoric acid, 4.59 percent; potash, 0.80 percent; sulfur (as SO_2), 1.68 percent; calcium (as CaO), 1.55 percent; iron (as Fe_2O_3) and over a dozen other trace elements, 6.63 percent (Adler, 1973). The use of sewage sludge as a fertilizer on land is an argument for using the sludge as a fertilizer in the ocean.

Nutrients added to the ocean could produce the equivalent of upwelling, the natural process of the upward flowing of nutrients from deep water to the surface waters where most marine organisms are found (Bascom, 1974). J. D. Isaacs of the Scripps Institution of Oceanography made this statement in Bascom (1974):

> The sea is starved for the basic plant nutrients, and it is a mystery to me why we should be concerned with their thoughtful introduction into coastal areas in any quantity that man can generate in the foreseeable future.

Municipal sludge is not significantly different from the fecal matter discharged by marine animals. Why should man believe that the sludge will be damaging to the ocean if the marine fecal material does not create destruction. This point was also backed by Isaacs (Bascom, 1974) in the following declaration:

> The six million metric tons of anchovies off southern California produce as much fecal material as 90 million people, that is, ten times as much as the population of Los Angeles, and the anchovies off course comprise only one of hundreds of species of marine life.

However, the nutrient load present in sewage sludge can also be considered a potential danger. A consequence of biodegradation of the sludge is the phosphorus and nitrogen compounds which remain after the degradation of the organic matter of the sludge (Foyn, 1971). These plant fertilizers, when introduced in large quantities, stimulate the growth and proliferation of marine species such as phytoplanktor and algae. Excessive growth of plants increases the turbidity level to the degree of low light penetration, and photosynthetic activity in the water masses below is greatly curtailed. Over-fertilization also causes a reduction of the diversity index, the types of species present.

Plankton blooms can also lead to toxic conditions such as the red tide. The appearance of this phenomenon is associated with over-fertilization. The dinoflagellates, which cause the red tide, live by waging chemical warfare upon other marine species. These blooms excrete a waste that immobilizes the nervous systems of fish (Marx, 1967).

The process of decomposition while providing fuel for plant production reduces the supply of oxygen in the water. This great oxygen demand may deplete the dissolved oxygen content to below the critical levels necessary for certain species of marine life.

Perhaps one answer to this question can be found in a statement (Behrman, 1969) by Dr. Pieter Korringa of the Netherlands Institute for Fishery Investigations:

> One cannot just fertilize the sea anywhere.
> When we enrich waters that are already rich,
> we get into trouble.

The key to this controversy depends upon the concentration and the hydrographic and biological conditions of the sea (Foyn, 1971). The point that has been brought out in this discussion is that an excess or uncontrolled discharge is harmful. Just as a farmer calculates how much fertilizer he can safely add to his land, so it should be with the discharge of sewage sludge in ocean waters. A controlled, monitored, and researched discharge program may shed some light on the controversy.

The Effect on the Balance of Nature

The ocean disposal of wastes offers the possible consequence of severely hampering the marine food chain. The cycle begins with phytoplankton, single-celled green plants, which are fueled by the action of the sun's visible light. Reduced growth of phytoplankton can even affect man on land. Phytoplankton productivity is a vital part in sustaining the marine food cycle. Marx (1967) states his opinion on the subject:

> The ocean dumping of industrial toxins, pesticides, sewage, and radioactive wastes haunts us because the marine food web absorbs and reincarnates these perilous discharges in the most apparently innocent forms.

Many varieties of phytoplankton synthesize organic material within the lighted surface layers of the open waters. Herbivorous zooplankton and some small fishes eat these plant cells; these in turn support nektonic, or actively swimming, predators. Inhabitants of the mesopelagic, bathypelagic and benthic zones devour organic debris and organisms as a result of vertical migration. Decaying organic detritus on the bottom sustains the phytoplankton through the process of upwelling, the flowing upward of nutrients. This typical food web as portrayed by Isaacs (1969) shows how the chain stretches link by link from plants through minute crustaceans to small fish through big fish and eventually to man.

Phytoplankton quantities affect all life. Helen Loeblich measured the growth rate of phytoplankton throughout geological history (Newman, 1970). Her study showed that each drop in the amount of microscopic plants coincided with and maybe led indirectly to the extinction of some animal species and can affect all forms of oceanic life, since all the organisms live within a single interconnected medium.

In the process of photosynthesis, phytoplankton release oxygen to the water which then is released to the atmosphere. Microscopic plants have been estimated to furnish 30 to 70 percent of the earth's oxygen level furnished by plants (Newman, 1970; Dallaire, 1971). Man should pay close attention to this fact since he is constantly reducing the vegetation of the land with all of his paving over millions of acres of land.

Studies have been conducted on various pesticidal compounds to determine their effects on phytoplankton productivity. One study showed that levels of 0.1 to 1.0 parts per billion of chlorinated hydrocarbons (DDT, dieldrin, and endrin) affected photosynthesis and growth in marine phytoplankton (Menzel, et al., 1970). Work by

Butler (1963) corroborated that pesticides reduced phytoplankton productivity. It is not known yet how other chemical compounds affect the growth rate.

The oceanic food web has also been changed by the accumulation of various compounds within tissues of marine organisms. The pesticide DDT is one substance which is known to pass through the food chain. Certain seabirds have high mortality rates at birth because of brittle egg shells. The egg shell thinness has been related to the birds' uptake of DDT from the marine food cycle. The birds ate fish which had eaten smaller forms of life containing DDT. Each step of the cycle concentrates the toxicant. Residue levels are also increased when organisms pass the compound on in the reproductive process to the young.

Disposal of waste materials in the ocean has the potential for upsetting the balance of nature. Disruption of the cycle can have far-reaching consequences on man. It is up to him to determine which materials will prove to be safe so the oceanic food web can continue as nature intended it to.

Health Risk

There is the possibility that ocean disposal of wastes may endanger the health of the human race. People are very concerned with risks that involve themselves. Just the hint of a health risk involved in ocean disposal causes more dissension against marine disposal of wastes.

Commoner (1971) feels that "increasing pollution of surface waters with organic matter breaks down the natural ecological separation of man and animals from soil pathogens and may open up a veritable Pandora's box of disease and toxic hazards." He believes that the multiple effects of these hazards may in the future become an intolerable threat to human health.

There are those who feel that ocean disposal of domestic sewage wastes presents little if any threats to human health. Adler (1971) pointed out several examples of existing sewage waste utilization on land. If waste sludge has been put to use without any resulting health hazard, then sludge disposal in the ocean is likely to be even less of a health risk than using it directly on food crops. Man does not drink seawater; therefore, his chance of receiving pathogens is reduced. Also, the sea is a hostile environment; the life span of pathogens is shorter in ocean water than in fresh waters.

On the other hand, some fear that the sewage wastes will become hazardous to people involved in water contact sports. Wakefield (1970) made a theory as how people came to fear sewage wastes:

> General public, knowing that such diseases as typhoid and poliomyelitis can be transmitted by fecal contact and having been educated to observe the principles of hygiene by washing their hands after a visit to the lavoratory, fear a sewage-polluted beach is a danger to health.

The standard method for measuring the potential public health hazard is the coliform bacterial count. Coliform bacteria which are harmless are used as indicators of the possible presence of pathogens. When the coliform count exceeds the standards set by the Food and Drug Administration, the area is closed to the harvesting of seafood. The problem with indicator organisms is that a direct relationship does not always exist between their presence and the actual presence of pathogens (U.S. Department of Commerce, 1974).

Sewage sludge and sewage effluent are the major sources of pathogens which cause diseases and illnesses. Hepatitis virus are known to be carried by shellfish. An outbreak of infectious hepatitis in 1961 was traced to raw shellfish taken from Raritan Bay, New Jersey (U.S. Department of the Interior, 1970). Shellfish have been found to contain polio virus concentrated to at least 60 times that of surrounding waters (Mitchell, et al., 1966). Fish can also become infected with pathogens over extensive distances.

Bioaccumulation and biomagnification of certain waste materials present a human health risk. Fish and shellfish can concentrate metals such as mercury. Over 100 cases of methyl mercury poisoning occurred in the vicinity of Minamata Bay, Japan (Marx, 1967). These cases, most of which ended fatally or in permanent, severe disability, were caused by the consumption of shellfish contaminated by effluent containing mercury from a chemical factory. Other metals can also endanger human health through accumulation to toxic levels.

Other compounds, particularly pesticide residues, concentrate in seafood. The substances often remain colorless and odorless, even after cooking (Council on Environmental Quality, 1970). Some hydrocarbons are known to cause cancer in man and animals. Cancer in humans could possibly be caused by the consumption of carcinogens from seafood. This is not yet proven, but it is worthy of investigation.

Human health is a factor, but not a particularly important one, in deciding which materials should be disposed of in the sea. Waste materials should be disposed of in areas where the substances do not have a chance to return to man in any form, or hazardous materials should not be disposed of in the ocean at all.

Acute Toxicity Versus Chronic Toxicity

The ocean disposal of waste materials presents a risk to the marine environment in terms of toxicities which result in lethal or sublethal effects. Acute toxicity, which is commonly recognized as the concentration of a compound that results in greater than 50% mortality to a selected species within a given time period, is of the most concern to the public. Death is a term which people can relate to; therefore, they show the most interest in the compounds that cause death of the marine life.

Chronic toxicity can be defined as the concentration of a compound which produces a noticeable but not lethal effect to an organism. These toxicities cause damage to marine organisms and may, in some instances, result in death to the organism. The chronic effects of materials are usually subtle and more difficult to detect. The consequences of chronic levels are often long-term and produce varied results. The effects can be grouped into three broad categories: behavioral; physiological; and bioaccumulation and biomagnification. These outcomes can be caused or enhanced by such factors as synergism and degradation.

Marine organisms react differently to different substances introduced into their environments. Some fish, for example, will exhibit an avoidance response to the compound and may stay away from it or swim around it (Hansen, et al., 1974). In some cases, egg laying or hatching is delayed due to the presence of a foregin material (Cope, et al., 1970). Feeding habits and migratory routes can be disrupted by the presence of a toxicant. These can have a far-reaching effect on the proliferation of the species.

Various physiological changes or effects are produced. Disruption of enzyme systems, shell deposition, and osmoregulatory functions are few of the many results (Lowe, et al., 1971; Janicki and Kinter, 1971; Butler, 1963). The physiological changes experienced by organisms can eventually lead to death or make an organism more susceptible to stress or disease. For example, the antibody production in carp is reduced when exposed to chronic levels of phenol (Goncharov and Mikryakow, 1971).

Bioaccumulation and biomagnification is known to occur in certain compounds, particularly pesticides. The toxins which build up in the tissues of the organism may not show up for many generations of that species. The compound might not prove to be toxic until enough of it has accumulated. Oysters in waters with 0.001 parts per million of dieldrin can magnify the concentration 1000-fold in tissues after 10 days (Wilson, 1965). Grass shrimp exposed to 2.3 parts per million concentrated it 11,000 times in their tissues (Nimmo, et al., 1974).

Synergism is the coupled action of compounds whose total effect is greater than the sum of the effects taken independently. Although studies may indicate a waste material is suitable for ocean disposal, the effects of the waste on aquatic systems when coupled with other materials, present either as the result of runoff, direct disposal, accidents, or natural background levels, is still unknown. If individual compounds have the potential for being dangerous by themselves, their combined effects may present a greater danger.

The controversy is whether waste materials to be disposed of are allowed according to their acute or chronic effects. Most of the research has been conducted on laboratory organisms to determine acute effects. Another problem is that the test procedure will not give the same results as the open ocean system. Yet these studies are necessary and should be conducted to cover all phases of chronic toxicities. Many feel that the slow deterioration of the marine environment caused by chronic levels is more destructive than short-term acute levels in the long run. Moorcraft (1973) is one of this opinion:

> More damage can be done to a species and an ecosystem by a substance which slows down or distorts its life processes than by one which kills outright.

Local Impact Versus Global Impact

The impacts of ocean disposal can be divided into two categories: local and global. Local impacts affect the immediate area surrounding the disposal site. Local impacts are functions of the waste staying put and decay within a reasonable time in a local system. For example, the New York Bight is also an area where local impact can occur. A global impact can be the wide transport of a single waste or the shorter transport of wastes from many sources. These two categories of impacts are differentiated not only geographically, but also according to the type of materials disposed of in the ocean.

Conservative materials, those that bioaccumulate or biodegrade slowly, have the potential for global impacts. Persistent synthetic compounds (pesticides, PCB's, etc...) disposed of in one area can be transported vast distances virtually unchanged. Classic examples are the discoveries of DDT and PCB's in Arctic and Anarctic mammals. This illustrates the world-wide distribution of dangerous compounds. Small marine life bioaccumulate and even biomagnify certain compounds; this starts the movement of these compounds through the universal food chain. Many of the organic wastes such as sewage sludge are easily degraded locally, therefore only affecting the disposal area.

Since all the major bodies on earth are linked, it is conceivable that materials disposed of in one location may eventually end up somewhere else. Accordingly, Thor Heyerdahl contends there is no such thing as "national waters", because the sea is in constant motion (Marine Pollution Bulletin, 1974). The water off the coast of Africa now may shortly wind up in Barbados.

Man is violating two cornerstones for preservation of his water environment - "keep your own home clean and don't dump in your neighbor's backyard" (Stander, 1975). When man shows concern over what he disposes of locally, then all the oceans of the world will benefit.

Out of Sight, Out of Mind

The well-known cliché "out of sight, out of mind" originates from the popular belief that if man does not see the waste, then why should he worry about it. The average man does not associate with the ocean everyday; therefore, why should he not put his wastes in it. The ocean means the most to those who depend on it for their subsistence.

According to Roger Revelle, the ocean basins are just great holes in the ground (Behrman, 1969). Man, as a land mammal, tends to think of the ocean as alien to his normal life and it seems logical to him that he should hide his wastes in the sea.

Effects of ocean disposal have to be tangible before people start caring about them. What happens to wastes dumped in the sea is not man's concern as long as these waste materials do not show up again in his lifetime (Bourne, 1972). What happens a hundred or a thousand years hence is not his worry. He just passes the problem on to the next and subsequent generations.

People who do not conform to this known expression believe that "the ends justify the means." Although man does not see the waste materials in the ocean, the harmful effects of the wastes will eventually catch up with him. Man should not forget that the waste has to go somewhere. What happens to the waste materials today may turn out to be a rude shock to some industries or fisheries a few years later (Hedgpeth, 1970). The ocean may seem remote to many people, but, of every hundred breaths man takes, seventy come from the oceans (Bourne, 1972).

The Layman's Viewpoint

A layman is a person not knowledgeable in a particular profession. In this case, the profession would involve those who are engaged in the practice of ocean disposal. For example, laymen would include those who depend upon the ocean for a livelihood and those who utilize the ocean for recreational purposes.

One reason why laymen became more aware of ocean disposal was through the influence of the medium of press, radio, and television. Years ago the idea of ocean pollution meant very little to laymen. Now that the laymen realize ocean disposal may pose a threat, they are more open in their denouncements of ocean disposal.

Laymen also became more conscious of ocean disposal of wastes when ocean pollution became visibly evident. Fishermen were first made aware of effects when they found themselves being robbed of their catch. Divers also found destruction of their sport. On the beach, obvious evidence washed ashore where one could see a collection of unattractive flotsam amongst the driftwood and seaweed.

For example, C. E. Jones, a fisherman, charged that since industries began dumping their wastes into the Gulf of Mexico, the Flower Garden coral reefs have turned from an incredible fish factory into a lifeless "brown blob" (Scarlett, 1976). He had no proof as to what caused the destruction; he only expressed his thoughts of concern. These laymen have a different perspective of the ocean than the industries and municipalities who dispose of their wastes in the ocean. Laymen are in closer contact with oceanic life and honestly care what happens to it; whereas those who ocean-dump are concerned with staying within the limits of the permits to protect the marine life.

Laymen follow their emotions rather than all the technical facts. When there are less fish, coral reefs and other marine life, the blame is put upon ocean disposal or any other available reason without examining other causes. There are other ways that ocean pollution can occur such as accidents and natural phenomena, but these are not always taken into consideration. Science is a very difficult field to understand and laymen often lack knowledge in this area. The laymen only want to do what is right for the preservation of marine life.

Aesthetics

Aesthetics is a branch of philosophy dealing with the nature of the beautiful. The ocean is one of the natural beauties of the world. It has been portrayed in works of literature as being majestic and lovely. Even people who have never seen the ocean tend to think of it as an object of splendor. The oceans and their shore areas offer some of the most scenic attractions of the United States.

Ocean disposal of wastes is viewed by some as a threat that causes the loss of the ocean's quality of being pleasant or agreeable. Materials that float on the water's surface pose a major threat to amenity values. Some floatables cluster together to form clumps of litter, while others form a film or sheen. Thor Heyerdahl, after sailing across the Atlantic, described the samples of man-made debris collected in mid-ocean as being gummy asphalt-like globules of oil, ranging in size "from peas to potatoes" (Newman, 1970).

There are certain materials such as dredged materials and sewage sludge that can increase turbidity and change the color of the water. Heyerdahl on his sea expedition also found discoloration at one point (Newman, 1970):

> The sea assumed a very dirty grayish-green color instead of clear blue, leaving us with the impression of being inside a harbor amidst the outlet of city sewers.

Ocean pollution also includes degradation of some wastes which produce unpleasant odors. This could be caused by rotting algae or anaerobic waters which also cause visual pollution.

The disposal of sewage sludge has vulgar connotations associated with it. One author (Soucie, 1974) describes it as vile stuff in the following description:

> Down at the center of the dumping ground it resembles black paste, or black mayonnaise when it is contaminated by oil, as it often is. Out near the periphery of the dump it is more like black talcum powder mixed with sand.

Naturally people would not want anything like this contaminating their swimming areas and washing ashore on their beaches. Some scientists claim that sludge has moved from its disposal site in the New York Bight to within five miles of the beach (Soucie, 1974).

Ocean pollution causes loss of beauty which leads to a reduction in water recreation. Floating debris, films, discoloration, and odors are very unpleasant and disagreeable. Society wants the ocean and its shores to be available for boating, water skiing, fishing, swimming and viewing at all times.

If ocean disposal of wastes poses the consequence of destroying the aesthetic values of the ocean, the public will shout to prohibit ocean disposal. People want nature to remain in its original form so that they and future generations can enjoy its beauty.

Influence of Environmentalists

Many of the well-known environmentalists have been responsible for publicizing the condition of the oceans. These people have been very effective in reaching the emotions of the general public. Since the 1960's, the environmental movement has reached proportional heights.

Many have heard Thor Heyerdahl, Jacques Cousteau, Barry Commoner, Wesley Marx, Rachel Carson and others decry the condition of the ocean. The resulting publicity created by their emotional appeals has influenced the passage of laws dealing with ocean discharge. When enough of the voting public expresses its opinions to halt or curtail ocean disposal, the politicians aim to please the voters in passing legislation. One must question how much scientific research has gone into these environmentalists' proclamations which have led to laws.

John Macdox (1972) has labeled these people as "prophets of doom." Some have preached that the environment is doomed and man does not have long to live on this planet. An example of approaching calamity was made by Jacques Cousteau when he estimated that "40 percent of the world's marine life has disappeared because of industrial pollutants in the sea, and the rest is on its way out" (Adler, 1973). Another recognized explorer, Thor Heyerdahl, stated that "to destroy the ocean is to kill our planet" (Marine Pollution Bulletin, 1974). A further example of lugubrious pronouncement was made by Dr. Jacques Piccard when he said that "at the current rate of pollution there would be no life in the oceans in 25 years" (Adler, 1973). Also an interim study released by Sandy Hook Marine Laboratory indicated that sludge-dumping had turned a 20-square-mile area in the New York Bight into a "dead sea" (Dallaire, 1971). After hearing proclamations of disaster like these, why should not the public be in an uproar over the condition of the oceans.

There are two reasons why the public should be cautious in heeding the words of these ecologists(Maddox, 1972). First, the processes which are to lead to disaster are not always understood. Second, the scale of the local effects on the oceans is small compared with the entire ecosphere. If the public always first clearly thought out their reasons for ostracizing ocean discharge, rather than following their emotions, perhaps rational conclusions could be made concerning ocean disposal.

An important point was brought up by Maddox (1972) when he questioned why less emotional energy is spent on other threats to human life and happiness: poverty, injustice, and avoidable death. People should give equal attention to problems closer to home.

The Human Factor

The term "human factor" is associated with the idea that man gets away with what he can. He will carry out an act of possible wrong as long as he knows he will not get caught in the process. This idea can be applied to ocean disposal in that some materials might get dumped illegally if no one else knows about it.

Man might justify his unlawful act of disposing of his wastes by extenuating circumstances. An operator of a barge disposal operation might have the wastes dumped before reaching the disposal site due to conditions of the trip such as bad weather.

The practice of ocean disposal might also be abused by those who are only concerned with the cost. Rather than travel 140 miles out to dispose by barge, the operator may just go 50 miles, which would certainly cut the cost down. Abusers may also dispose of materials other than those allowed.

Opponents of ocean disposal feel that doing away with this practice entirely will stop this illegal dumping. This idea can be refuted in that ocean disposal does not condone these illegal acts. It is wrong to associate unlawful disposal with regulated ocean disposal. There are laws to obey and those caught in the wrong are punished. More of these wrongdoers are more apt to be caught if ocean disposal is allowed to continue under regulation. One cannot assume that man's nature will overcome him, in other words, wrong over right, when he is granted permission to dispose of materials in the ocean.

Lack of Knowledge

The ocean still contains many mysteries unknown to man. Oceanography has been studied for many years, but little research has been done concerning waste disposal in the ocean. Little is known of the effects of early, unregulated ocean disposal. Before permits were required, the wastes were disposed of in the ocean with little regard to its effects.

Perhaps one reason for limited knowledge in this field is that man has turned his efforts to conquering space. Much time and money has been spent in exploring the realm of space for future use. If as much consideration was given to the study of ocean disposal, information would probably be available as to how waste materials would affect the sea. Dr. Schneider, director of EPA's National Marine Quality Laboratory, made the following comment: "We know more about the moon's backside than we do about the bottom of the ocean" (Heckroth, 1973).

Another problem that occurs is the dissension among the technologistsand scientists (MacLeish, 1975). What the technologists have learned to do, many scientists are not sure should be done. Those who solve the problems of marine disposal technicalities are confident; whereas, those who measure stress within the marine environment are cautious. Caution is necessary until man has all the facts at hand.

Man is just now turning his efforts and research toward the oceans. He is realizing that the oceans may feed and provide an energy source for society in the future. With these realizations and others, ocean disposal is being critically examined. It will be a few years before the necessary knowledge is obtained to provide for adequate management of the oceans.

Before man can even plan methods of ocean disposal, he must understand the ocean, its tolerances and stresses (Marx, 1969). His most certain knowledge of how to control nature to his advantage rests not in his ability to tamper with the system, but to reduce his impact upon the environment (Hedgpeth, 1970). This is what man has yet to learn. When harm comes to the ocean due to the practice of marine disposal, those involved who think they understand the ocean often stand back and ask, "Now how did that happen?"

Argument of Unrealistic Legislation

There is the question of whether the present legislation is sufficient to protect the marine environment. Those who desire to ocean-dump must first obtain a permit under the regulation set by the Environmental Protection Agency as specified by the Marine Protection, Research and Sanctuaries Act of 1972 (P.L. 92-532).

Non-supporters of the present legislation claim the base of knowledge needed for ocean pollution standards is unavailable. The standards and guidelines were set in great haste based entirely on inadequate information. Without having all the facts at hand, will these laws really do any good? Bascom (1974) supports the idea of insufficient legislation by the following passage:

> No one would dispute the wisdom of protecting the sea and its life against harm from man's

> wastes. An argument can be made, however, that some of the laws the U.S. and the coastal states have adopted in recent years to regulate the wastes that can be put into the oceans are based on an inadequate knowledge of the sea. It is possible that a great effort will be made to comply with laws that will do little to make the ocean cleaner.

Government intervention is both necessary and justified because industries and municipalities, in their efforts to minimize costs, have little regard for the social values of the ocean. During the era of unregulated dumping, industry used the ocean as a waste receptacle for anything as desired. Since the enactment of the present laws, the number of ocean disposers has decreased dramatically. The standards adopted by the government were purposely designed to contain the tendency towards ocean pollution, and the laws have been effective in fulfilling that purpose. As man's knowledge of the marine ecosystem increases, hopefully the standards will be adjusted accordingly.

Argument of Alternative Disposal Methods

Those who favor alternate disposal practices feel there is no need for ocean waste disposal, since the waste materials could be rendered ineffective by one or more of the following alternatives: sanitary landfill, land disposal, incineration, carbon adsorption, deep-well injection, biological treatment, chemical reduction, ultrafiltration, and recycling. Use of alternate methods will keep the ocean from becoming polluted through marine waste disposal.

There is disagreement about whether these alternatives will be more beneficial to man in the long run. This leads to the idea that "abatement pollutes." Alternate disposal practices could result in the pollution of natural resources other than the ocean. Since the wastes cannot be totally destroyed, they have to go somewhere: land, air, and water, mainly rivers and estuaries. For example, if ocean disposal is curtailed, the aqueous organic waste solutions currently dumped will have to be treated before discharge to rivers and estuaries. The materials and processes required for upgrading the effluent, such as ion-exchange resins, aerobic digestion plants, etc., will themselves produce wastes which will require disposal. The problem of pollution would merely be shifted elsewhere. Thus, pollution abatement in this sense generates more wastes than it removes and also, consumes more natural resources in the process.

Incineration is a viable alternative for completely combustible wastes because, in addition to getting rid of the waste, steam is generated and heat can be recovered. However, a highly aqueous waste would require large quantities of natural fuel. This practice would further deplete the fuel reserves. If there is a residual ash left after incineration, this remaining material will have to be ultimately disposed of on land. Air pollution is a distinct possibility, since incineration merely shifts the contaminants from a liquid sea to a gaseous sea.

Deep-well disposal uses injection pressures which may reach a critical point great enough to fracture confining formations or damage parts of the injection system, allowing fluids to escape into surface or subsurface waters. Thus, contamination of the drinking water supply is a possibility. The fluids injected have to be somewhat compatible with the area they are injected into. Some wastes may not meet this requirement, and thus cannot utilize deep-well injection.

Alternatives to ocean dumping of dredged materials would involve filling in areas near the shore or building dikes. Then the contaminated dredged material must be kept from interacting with surrounding waters. The filled-in area would not be strong enough to build on for several years, making these shore areas unusable.

Land is becoming scarce, especially for man to use for waste disposal. Many of these alternate methods require much land area, particularly landfill and land disposal. There is also the problem of the wastes decomposing slowly or not at all. This could impart odor, taste, and even toxic characteristics to the soil and groundwater. Disposal of wastes on land concentrates the wastes in one location. Some say it can be controlled and monitored effectively this way. Disposal in the ocean spreads the waste over an infinite area and it usually cannot be accounted for after a period of time.

Recycling and reuse of the wastes could be the only solution to preventing pollution. Yet man has not found a way to reuse these waste materials in an effective manner. The recycling and reuse of wastes is a very costly process, often more expensive than the raw materials. Some feel that this alternative costs more than it is worth.

Most of the alternate disposal methods require more manpower, equipment, energy, and time. This means the company or municipality will have to invest additional money in installing and maintaining these waste treatment facilities. Ocean disposal of wastes not only demands less money, but also less effort on the part of man.

Economics

The majority of the people in this country are very concerned with the economy. They look for ways to save money in all facets of life, including waste disposal. Rawn (1966), one of the officials associated with the development of the sewer outfalls of Los Angeles, made the following statement which sums up for many how they feel about the economy of oceanic waste disposal:

> If the ocean, or one of its arms, can be reached with a sewer outfall, within the bounds of economy, the grim spectre of an expensive complete treatment plant grows dimmer and dimmer until it fades entirely and, to the great satisfaction of those who have to gather funds for the public budget, as well as they (you and I) who have to pay the bill, the good old ocean does the job free.

This declaration applies not only to sewage, but also to the other wastes. It is the people who have to pay the cost of disposal.

The cessation of ocean disposal activities in those areas where it is a widespread practice, particularly the New York Bight, would seriously hamper the expansion and growth of the involved industries because of the large capital outlays required for alternate disposal. Although the expense involved in constructing waste treatment facilities and pollution control equipment might force old or marginal plants to close or cut back their operations, this is a necessary step in pollution abatement. Modern plant facilities are more capable of absorbing the additional capital required. Unemployment may occur, but it is a short-lived phenomenon and it would be balanced by the construction of new facilities.

Anyone utilizing the practice of marine disposal must realize that pollution control is not an added expense, but an inherent part of his process. When told to install costly control equipment, the entity threatens to raise the prices of its products. It is the consumer who must decide between two alternatives. He can pay the cost of polluting the ocean if ocean disposal continues or he can pay the price increase in products after the installment of pollution control apparatus.

Cost analysis of alternatives shows them to be expensive. Ocean disposal is shown to be a much less expensive method. But, one must remember that transportation is the only expense calculated in ocean disposal. Man has not calculated the potential damage to the ocean in his cost analysis. The true cost of damage to the ocean may not be realized for many years. A price tag cannot be placed on the ocean's environment.

Eocnomics also involves significant money losses when the ocean becomes polluted from waste disposal. Significant losses are incurred when seafood species are reduced in number or rendered inedible by the pollution. Many areas are closed due to unsafe levels of contaminants. Even when contamination levels are not above the standard, the seafood may be discolored or tainted.

Another cost is that of cleaning up polluted shore areas. Some forms of waste are capable of floating back and littering these areas. Recreational activities would be seriously hampered or even discontinued in contaminated areas.

Many people depend upon the ocean for their subsistence, whether they be involved in seafood activity or recreational activity. Man does not have the right to rob people of their livelihoods. If ocean disposal is to continue, man should see to it that the wastes will not bring about serious economic losses.

An Irreversibly Polluted Ocean

Marine disposal of waste materials whose bioaccumulation, biomagnification, and behavior-impairment abilities are unknown could result in an essentially polluted ocean. Such a situation could be termed irreversible because there are no techniques available for the waste treatment of oceans. It is not even feasible for man to think that he can clean up the ocean pollution he causes by putting wastes in the ocean. System regeneration by natural processes occurs for some materials on a geologic time scale. This does not repair the damage done to the ocean fast enough to really make any differences. The ocean system is geared to cycles of thousands of years - not to the frantic pace of human development.

The consequences of man abruptly altering an environment developed over long periods of time are the disappearance of useful species, appearance of nuisance species, noxious conditions and health hazards. Once a species is totally exterminated, there is no way to bring it out of extinction. Formation of nuisance species in turn can destroy other species. The "crown-of-thorns" starfish population has rapidly reproduced; the starfish which feed upon coral reefs threaten to destroy the reefs which are food sources for many other organisms. There is the possibility that this ecological disturbance is caused by the actions of man. Species also disappear due to the accumulation of compounds within their tissues. Organisms pass on these compound that have built up to subsequent generations. Eventually death can occur and wipe out a species.

CHAPTER IV

SUMMARY

The technical and philosophical aspects of ocean disposal can be summarized in terms of their relationships to each other. These correlations are shown according to degree of relatedness on matrix-style illustrations: relationships between technical issues (Figure 4.1), relationships between technical and philosophical aspects (Figure 4.2) and relationships between philosophies (Figure 4.3). How the issues relate to each other in some cases is obvious, while in other instances the degree of relation is only slight.

The correlations between the technical issues discussed in the text are very closely entwined. Many of the issues have high ratings for their relationships, because they are important in determining the characteristics of each other. For example, the qualities of the waste are influential in determining how much can be discharged at a particular site without harming the marine environment. Materials to be disposed of in the ocean and their limiting permissible concentrations are closely regulated by provisions of the appropriate laws. Permits limit the waste quantities. Disposal methods are selected according to waste type, and transport of the waste throughout the water column is dependent on the qualitative and quantitative aspects of the waste material. The waste characteristics are important in seeking a suitable alternative.

	DESCRIPTION OF WASTE	WASTE QUANTITIES	DISPOSAL METHODS	TRANSPORT MECHANISMS WITHIN THE WATER	DISPOSAL SITES	EFFECTS OF DISPOSED WASTE	LEGISLATION	CRITICAL OR ALLOWABLE QUANTITIES	DISPOSAL ALTERNATIVES	FUTURE TRENDS
DESCRIPTION OF WASTES		H	H	H	H	H	H	H	H	M
WASTE QUANTITIES	H		M	M	M	M	H	M	M	H
DISPOSAL METHODS	H	M		H	M	M	M	N	N	L
TRANSPORT MECHANISMS WITHIN THE WATER	H	M	H		H	H	L	M	L	L
DISPOSAL SITES	H	M	M	H		H	H	M	L	M
EFFECTS OF DISPOSED WASTE	H	M	M	H	H		H	H	H	H
LEGISLATION	H	H	M	L	H	H		H	H	H
CRITICAL OR ALLOWABLE QUANTITIES	H	M	N	M	M	H	H		N	M
DISPOSAL ALTERNATIVES	H	M	N	L	L	H	H	N		H
FUTURE TRENDS	M	H	L	L	M	H	H	M	H	

LEGEND

H HIGHLY RELATED
M MODERATELY RELATED
L SLIGHTLY RELATED
N NOT RELATED

FIGURE 4.1. RELATIONSHIPS BETWEEN THE TECHNICAL ASPECTS OF OCEAN DUMPING

	SIGNIFICANCE OF THE OCEAN	ULTIMATE SINK	INFINITE SINK	CONSERVATION OF MATTER	ASSIMILATION CAPACITY	MIXING AND DILUTION	OCEAN vs. ESTUARY	WASTE or NUTRIENT	BALANCE of NATURE	HEALTH RISK	ACUTE TOXICITY vs. CHRONIC TOXICITY	LOCAL IMPACT vs. GLOBAL IMPACT	OUT of SIGHT, OUT of MIND	LAYMEN'S VIEWPOINT	AESTHETICS	INFLUENCE of ENVIRONMENTALISTS	HUMAN FACTOR	LACK OF KNOWLEDGE	UNREALISTIC LEGISLATION	ECONOMICS	DISPOSAL ALTERNATIVES	IRREVERSIBLY POLLUTED OCEAN
DESCRIPTION OF WASTES	H	L	L	L	H	H	M	H	H	H	H	H	M	M	H	M	N	M	L	M	H	H
WASTE QUANTITIES	M	L	H	M	H	H	L	H	M	L	M	M	M	L	M	L	L	L	L	L	M	M
DISPOSAL METHODS	N	L	L	N	M	H	M	L	L	L	L	L	L	L	L	L	M	L	L	M	M	L
TRANSPORT MECHANISMS WITHIN THE WATER	L	M	M	L	H	H	L	L	H	M	M	H	M	N	M	N	N	L	L	N	M	L
DISPOSAL SITES	M	M	H	L	H	H	H	M	M	M	M	M	M	M	M	L	M	M	M	L	M	L
EFFECTS OF DISPOSED WASTES	H	L	M	M	H	H	M	H	H	H	H	H	M	M	H	M	L	H	M	H	M	H
LEGISLATION	L	L	L	L	L	L	L	M	M	M	M	L	L	M	M	M	N	H	H	L	H	M
CRITICAL OR ALLOWABLE QUANTITIES	L	N	M	L	L	L	M	M	H	H	H	M	L	N	L	L	N	M	M	M	M	H
DISPOSAL ALTERNATIVES	M	H	L	M	L	L	M	N	L	M	L	L	L	M	M	M	N	M	M	H	H	M
FUTURE TRENDS	H	M	M	M	M	M	L	H	M	H	M	M	L	L	M	M	L	M	M	M	H	M

LEGEND

H HIGHLY RELATED
M MODERATELY RELATED
L SLIGHTLY RELATED
N NOT RELATED

FIGURE 4.2. RELATIONSHIPS BETWEEN THE TECHNICAL AND PHILOSOPHICAL ASPECTS OF OCEAN DISPOSAL.

	SIGNIFICANCE OF THE OCEAN	ULTIMATE SINK	INFINITE SINK	CONSERVATION OF MATTER	ASSIMILATION CAPACITY	MIXING & DILUTION	OCEAN vs. ESTUARY	WASTE or NUTRIENT	BALANCE of NATURE	HEALTH RISK	ACUTE TOXICITY vs. CHRONIC TOXICITY	LOCAL IMPACT vs. GLOBAL IMPACT	OUT of SIGHT, OUT OF MIND	LAYMEN'S VIEWPOINT	AESTHETICS	INFLUENCE OF ENVIRONMENTALISTS	HUMAN FACTOR	LACK OF KNOWLEDGE	UNREALISTIC LEGISLATION	ECONOMICS	DISPOSAL ALTERNATIVES	IRREVERSIBLY POLLUTED OCEAN
SIGNIFICANCE OF THE OCEAN		L	M	M	M	M	M	M	M	H	M	M	L	M	H	N	N	L	L	L	N	N
ULTIMATE SINK	L		M	M	M	M	M	L	L	L	L	L	M	M	M	L	N	L	L	L	M	M
INFINITE SINK	M	M		M	H	M	M	M	L	L	L	M	H	M	L	L	N	L	L	M	L	M
CONSERVATION OF MATTER	M	M	H		L	L	L	L	M	L	L	L	L	N	L	L	N	L	L	L	L	L
ASSIMILATION CAPACITY	M	M	H	L		H	H	H	H	H	H	H	M	L	M	N	N	M	L	L	L	M
MIXING AND DILUTION	M	M	M	L	H		H	H	H	H	H	H	L	L	L	N	N	N	L	L	L	N
OCEAN vs. ESTUARY	M	M	M	L	H	H		M	H	M	M	L	M	L	M	M	L	L	L	M	L	H
WASTE OR NUTRIENT	M	L	M	L	H	H	M		H	M	M	L	L	L	M	M	M	M	M	L	L	M
BALANCE OF NATURE	M	L	L	M	H	H	H	H		H	H	H	L	L	L	L	L	M	L	M	L	H
HEALTH RISK	H	L	L	L	H	H	M	M	H		H	M	L	M	L	M	L	M	M	H	N	M
ACUTE TOXICITY vs. CHRONIC TOXICITY	M	L	L	L	H	H	M	M	H	H		H	L	L	L	L	N	H	H	M	M	H

LEGEND

H – HIGHLY RELATED

M – MODERATELY RELATED

L – SLIGHTLY RELATED

N – NOT RELATED

FIGURE 4.3. RELATIONSHIPS BETWEEN PHILOSOPHIES

	SIGNIFICANCE OF THE OCEAN	ULTIMATE SINK	INFINITE SINK	CONSERVATION OF MATTER	ASSIMILATION CAPACITY	MIXING & DILUTION	OCEAN vs. ESTUARY	WASTE or NUTRIENT	BALANCE of NATURE	HEALTH RISK	ACUTE TOXICITY vs. CHRONIC TOXICITY	LOCAL IMPACT vs. GLOBAL IMPACT	OUT OF SIGHT OUT OF MIND	LAYMENS VIEWPOINT	AESTHETICS	INFLUENCE OF ENVIRONMENTALIST	HUMAN FACTOR	LACK OF KNOWLEDGE	UNREALISTIC LEGISLATION	ECONOMICS	DISPOSAL ALTERNATIVES	IRREVERSIBLY POLLUTED OCEAN
LOCAL IMPACT vs. GLOBAL IMPACT	M	L	M	L	H	H	L	L	H	M	H		L	M	L	L	N	M	L	M	N	M
OUT OF SIGHT, OUT OF MIND	L	M	H	L	M	M	M	L	L	L	L	L		M	M	L	L	M	N	M	L	L
LAYMEN'S VIEWPOINT	M	M	M	N	L	L	L	L	L	M	L	M	M		M	H	M	M	M	M	L	L
AESTHETICS	H	M	L	L	L	L	M	M	L	L	L	L	M	M		M	L	L	L	H	M	L
INFLUENCE OF ENVIRONMENTALISTS	M	L	L	L	N	N	M	M	L	M	L	L	L	H	M		N	N	N	L	N	L
HUMAN FACTOR	N	N	N	N	N	N	L	N	L	L	N	N	L	M	L	N		L	L	M	N	L
LACK OF KNOWLEDGE	L	L	L	L	M	M	L	N	M	M	H	M	M	N	L	M	L		H	N	L	M
UNREALISTIC LEGISLATION	L	L	L	L	L	L	L	M	L	M	H	L	N	M	L	M	L	H		L	H	L
ECONOMICS	H	L	M	L	H	L	M	M	M	H	M	M	M	M	H	L	M	N	L		H	M
DISPOSAL ALTERNATIVES	M	M	L	L	L	L	L	L	L	M	M	N	L	L	M	M	N	L	H	H		M
IRREVERSIBLY POLLUTED OCEAN	M	M	M	L	M	M	L	M	H	M	H	M	L	L	L	L	L	M	L	M	M	

LEGEND

H - HIGHLY RELATED
M - MODERATELY RELATED
L - SLIGHTLY RELATED
N - NOT RELATED

FIGURE 4.3. RELATIONSHIPS BETWEEN PHILOSOPHIES (continued)

In selecting a disposal site, the characteristics and effects of a particular waste material need to be known. How the wastes affect the area is largely determined by the interactions between the disposed of materials and transport mechanisms of the water. Disposal sites have to be designated and approved by the Environmental Protection Agency.

The law requires the present dumpers to be seeking viable alternatives in order to eventually phase out ocean disposal. However, the increasing amounts of wastes due to the goal of zero discharge in rivers and bays may force a return to ocean disposal if the wastes are shown to have less harmful effects in the marine environment than on the land. The future may also bring about a change in the limiting permissible concentration, as defined by law.

Relationships exist between the philosophies and technical issues because the technical aspects have formed the basis for the philosophies. From their knowledge of technical information, people have formulated their opinions and beliefs of ocean disposal. People are not always adequately informed, therefore, some may have misconceptions related to philosophies.

People are concerned with the effects of marine disposal because they are affected by this issue. When man knows that waste disposal can be a hazard to his health, or livelihood, man will think twice about whether ocean disposal is a suitable method. Effects of waste materials are also the basis for the opinion that the balance of nature could be upset by waste disposal. It is a fact that a broken link in the marine food chain can affect man. The controversy centered on whether a material is a waste or nutrient stems from the effects of the material. Certain substances cause damage to the marine ecosystem, while others have potential nutrient value that may enrich the ocean's waters.

The type of waste materials discharged in the ocean has also stimulated people to form philosophies. The term "waste" has connotations associated with it, particularly the idea of sewage wastes. This stems partially from people's upbringings. To many, sewage is a vile substance, and they do not like the thought that their recreation waters might contain such materials. Aesthetic values are reduced and the economics suffer.

The forming of one opinion into a philosophy often leads to another philosophy. Environmentalists have been effective in influencing the general public. People who claim they are out to save the environment can also cause harm. Many lack the knowledge to make such proclamations, but often laymen do not know the difference. Environmentalists are primarily responsible for waking up the public to marine pollution; this in turn led to the passage of laws designed to protect the ocean environment. Some claimed that the legislation is unrealistic, because it was formulated in haste to please the public.

Economics is another area of concern to man. He is very concerned about money losses which could be incurred due to ocean disposal of wastes. Money is very precious to man, and he is often very verbal in expressing this opinion. Economics is also affected by alternatives that the people who desire to dump are required to seek. Ocean disposal is often less costly than other methods. Man must decide whether he wants to pay the cost of prevention of marine pollution or pay the cost of having a polluted ocean.

Perhaps the most important belief is that man lacks adequate knowledge in the field of ocean disposal. Ignorance of a subject does not solve any controversies. For example, the cliché "out of sight, out of mind" stems from the belief that if man puts his wastes in the ocean they will not bother him there. This is wrong because certain materials have been shown to affect man in various ways, some of which he does not understand. He may find it difficult to comprehend the meaning of the food chain, hydrologic cycle or even toxicity ratings.

The fact that the present legislation only contains a provision for acute levels of substances to release to the ocean is a reflection of this lack of knowledge. Chronic levels can have even more far-reaching effects than acute levels. Bioaccumulation and bioconcentration produce chronic effects which may not show up for years, but the accumulated effect can be detrimental or even lethal. The chronic level should also be considered in determining whether the impact is global or local.

The future of ocean disposal is still questionable. There will always be a pro or con side to it, but man must weigh the consequences of retaining or eliminating ocean disposal in making his final decision. In order to do so, he has to seek all available information on the subject. If the knowledge is not available, he has to find solutions to unanswered questions such as the long-term effects. Man may discover that ocean disposal is the solution for disposing of uncontaminated waste materials that do not act as pollutants in the marine environment.

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